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EDITOR: EDWARD S. DANA.

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FOURTH SERIES.

VOL. VIII—[WHOLE NUMBER, CLVIII.]

WITH SEVEN PLATES.

NEW HAVEN, CONNECTICUT.
1899.



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PLATE I.

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Pentlandite,	Miargyrite,	Plumboferrite,	Rose Apophyllite,
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Chilenite,	Binnite,	Brucite,	Sombrerite,
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Zorgite,	Wittichenite,	Babingtonite,	Rhabdophanite,
Stromeyerite,	Aikinite,	Uralite,	Woodwardite,
Sternbergite,	Pyrostilpnite,	Riebeckite,	Fauselite,
Polydymite,	Rittingerite,	Tritomite,	Volborthite,
Grunauite,	Geocronite,	Meliphanite,	Beudantite,
Linnæite,	Lautite,	Kaliophyllite,	Planerite,
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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*Velocity of Electric Waves in Air*; by G. V. MACLEAN. (With Plate I.)

HERTZ determined the wave-length of electric waves in air in one of his experiments to be 9.6 m., with an anti-node 70 cm. behind the reflector. In the case of electric waves along wires he found the rate of propagation to be 2.8×10^{10} cms. per sec. He further proved, if slow oscillations were used, that the lengths of the electric waves along wires and in air without wires would differ, but if rapid oscillations were employed the lengths of the waves would be the same. The truth of this has been confirmed by J. J. Thomson and Lecher.

E. Sarasin and de la Rive* concluded from their experiments that the wave-lengths determined are independent of the dimensions of the oscillator and vary with the size of the resonator employed. They showed that the rate of propagation of electric waves through air without wires is sensibly the same as that along wires. Thus by using a resonator 26 cms. in diameter the length of the internode along wires was 1.12 and in air between 1.12 and 1.25 m., while a resonator 36 cm. in diameter gave the lengths to be 1.47 m., air between 1.4 and 1.8 ms. respectively. They claimed that the same oscillator gives rise at the same time to waves of different lengths, that the waves sent forth are not simple, but are complexes of an infinite number of different waves, in fact a continuous electrical spectrum is formed, and that the resonator used acts as an analyser picking out from the spectrum those waves whose period is peculiar to itself, and to these alone it responds.

* Bibliothèque Universelle, Archives des sc. phys. et nat., 3^e period, xxiii, No. 2, 1890, p. 113. Also p. 557.

Poincaré* and Bjerknes,† independent of each other, contended that the oscillator and resonator each set up their own vibrations, which are not necessarily related, and that the variation of the wave-length, when different resonators are used with the same oscillator, is not due alone to multiple resonance, as stated by Sarasin and de la Rive, but to the unequal rate of damping of the waves by the resonator and oscillator. If the rate of damping in the resonator is small in comparison with that of the oscillator, then Sarasin and de la Rive's theory holds; if, however, the rate of damping of the resonator is great in comparison with that of the oscillator, Sarasin and de la Rive's theory fails. The length of the internode does not alter when the same oscillator is used with resonators of different sizes, but it varies with the dimensions of the oscillator when the same resonator is employed; the wave-length being the same as is found when a method is employed in which no resonator is needed. "If the rates of damping of the oscillator and resonator are almost the same, the lengths of the waves they produce exercise the same influence upon the length of the internode measured."

Sarasin and de la Rive had also pointed out the necessity of having the oscillator and resonator in tune with each other, and more particularly so was this needful when the waves in air without wires were measured.

In the experiment about to be described, a new method was employed by which the direct determination of the period of the oscillator was found. The oscillator and resonator were tuned by using a special form of self-induction and capacity and balancing them. The resonators used by Hertz, and by the other physicists to whom reference alone has been made, were simple loops of copper wire which acted as the self-induction, while the capacity was two small metal spheres. The oscillators had very large capacities in comparison with those of the resonators.

In our experiment the form and size of oscillator and resonator, as also the dimensions of their self-inductions and capacities, are identical. The resonator here used is a specially devised coherer. Many attempts of late have been made to successfully employ the coherer to measure electric waves. The results have generally been to stamp the coherer as an instrument too capricious for such work. In this connection may be mentioned the work of Professor Murani.‡ He used a

* Poincaré, *Elektricität und Optik*, 1891. *Archives des sc. phys. et nat.*, xxv, p. 609, 1891.

† Bjerknes, *Wiedemann's Annalen*. Band xlv, p. 75, 1891.

‡ Studio della onde stazionarie di Hertz col mezzo di un coherer, del Prof. O. Murani del R. Istituto Lombardo. Milano, 1898.

Marconi coherer and a galvanometer. The readings of his galvanometer, as he moved the coherer farther and farther from the reflector, changed; no zero readings, however, were found and there was no regular increase or decrease in the readings. The following table is taken from his paper:

Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.	Distance of Coherer in cms. from Reflector.	Deflection of Galv. Needle.
2	12	60	15.4
5	13.4	65	16.0
10	16.2	70	17.0
15	16.3	75	16.5
20	16.4	80	16.2
25	15.5	90	15.8
30	15.8	100	16.2
35	15.5	110	16.5
40	15.8	120	16.0
45	15.5	130	16.3
50	15.5	140	16.4
55	16.0	150	17.2
		200	17.4

His results were submitted to Professor A. Righi, who with Professor Murani, concluded that the coherer was unsuitable for the measurement of stationary electric waves.

Le Royer and Paul von Bérchem* at Geneva, in April of 1894, used a coherer containing iron filings kept between two magnetized needles. Their results showed that the tube they employed had not a wave-length peculiar to itself and that it acted as an analyser and not as a resonator, and that it would serve to measure the electric wave-lengths in air.

The coherer here employed is one reduced to its elements. It might in fact be termed an electro-bolometer, and in general is not more difficult to use than the heat-bolometer.

Two globules of platinum, one mm. in diameter, are attached to the ends of two platinum wires 0.12 mm. in diameter and 1.7 cm. in length. These latter form spirals each of two convolutions about two iron terminals 1.5 mm. in diameter and 4 cm. in length. These terminals run through the center of the two brass caps of a glass tube 8.5 cms. long and 1.5 cms. in diameter. To one of the terminals was connected a mill-head screw, so that the platinum globules could be adjusted to any distance from each other. This constitutes the coherer proper. The glass tube is not exhausted; it serves merely to protect the globules from dust, dampness, or other external interferences. The coherer is placed in circuit with a large Volta-

* Bibliothèque Univ. Archives de Genève, xxxi, 1894, p. 558.

Pavia battery of peculiar construction giving a steady current, a resistance box in which a resistance of over 100 ohms is always kept, and a Direct Reading Mille-Ampère meter. The current is shunted by a suitable resistance before passing through the coherer.

The capacity and self-induction of the coherer are respectively two sheets of tin foil 14.5 cm. by 14.1 cms. shellacked to the sides of a glass plate 30.4 cms. long, 30.4 cms. wide and 5 cms. thick, and two copper wires 9.62 cms. long, and .3 mm. in diameter, parallel to each other and distant 5 cms. These two wires had two of their ends soldered to two strips of brush copper which latter made close contact with the tin foil, by means of hard wax; the other ends passed into two small binding posts on the caps of the coherer. The current through the coherer is governed by a key. This constituted the coherer or receiving circuit. All the wires used throughout the whole experiment were well insulated, twisted and kept as far as possible out of the direct course of the electric waves, so that any influence the wires might exert upon the results was reduced to a minimum.

The different parts of the coherer circuit can be seen in the photograph, Plate I.

The platinum globules were first brought into the slightest possible contact by carefully adjusting a micrometer screw. When such a contact had been effected was known by watching the motion of the Mille-Ampère meter needle. Upon causing a train of electric waves to pass the coherer, the resistance of the latter is lessened by the globules moving into closer contact, that is to say the globules are made to cohere. This augmentation of the globules is instantly evidenced by the increased throw of the Mille-Ampère meter needle.

The coherer here employed is the outcome of a great many experiments with Lodge coherers, Marconi coherers or Branly tubes. Tubes containing metal filings of all kinds and of different degrees of fineness, as iron, silver, platinum, copper, zinc, nickel, magnesium, brass, granulated arc carbon with copper, or brass, or iron terminals, either magnetized or non-magnetized, all proved to be unsuitable for measurement of the electric wave-lengths, in not possessing the proper degree of sensitiveness. They all had the common fault of not allowing the Mille-Ampère meter needle to return quickly to its zero reading. Decohering of the coherer in the present form is accomplished almost instantly by the elasticity of the platinum spirals, upon opening the circuit key. No tapping is required as in other kinds of coherers. In fact this form of a coherer alone of all tried gave good working results. Moreover, the above coherer at once shows the manner of action of

the ordinary metal filings coherer. The platinum globules are brought into slightest contact, the passage of an electric wave causes the globules to cohere more closely; thus the resistance to the battery current through the coherer is lessened, as is shown by the increased deflection of the needle. The cohering of the metal filings (in this case the two globules) seems to be due to an electrostatic effect produced upon them by the passage over them of the electro-magnetic waves. Further evidence of this will be given later.

Before concluding the description of the coherer, it will be of advantage to give an account of the oscillator circuit and its accessories.

The electric spark which sent forth the trains of electro-magnetic waves through the free air between the oscillator and coherer, was given out by a large Ruhmkorff coil in connection with a storage battery of 27 cells in parallel with a voltage of about 55.

The oscillator consisted of two platinum globules 1 mm. in diameter attached to the ends of a platinum spiral making two convolutions about copper terminals, exactly like those in the coherer. This oscillator was placed in the secondary spark gap of the Ruhmkorff coil. The oscillator globules were always kept 4 mms. apart from each other. The same kind and the same amount of capacity and self-induction were used as in the coherer circuit. The coherer and oscillator circuits were thus tuned to one another.

The primary spark-gap of the Ruhmkorff coil was removed to a distant mercury break. The mercury break was of special construction. Three storage cells drove a motor, which in turn caused a plunger to play in and out of a mercury glass cup. On opposite sides of the glass cup were secured a glass tube shoulder, 1 mm. or so above the level of the mercury. To these glass shoulders were attached rubber tubes, one leading from a water tank and the other to a sink. Water was siphoned from the tank through the glass cup, over the surface of the mercury. Thus the surface of the mercury was always clean. A pinch-cock was fixed to the first rubber tube so that the strength of the stream of the running water could be regulated and kept constant. When the stream of water was properly regulated, sparking at the oscillator could be continued for hours at a time, the sparks always being perfectly regular and uniform. Before the addition of the stream of water over the surface of the mercury, the break gave endless trouble, needing attention almost every two or three minutes, but under the conditions adopted it required very little attention. However, care had to be taken to prevent a too free flowing of the water, for otherwise the nature of the

sparkling at the oscillator was much altered, too much water acting like too little. Wires ran from the break to the Ruhmkorff coil and also to a key at the coherer carriage. Thus from the coherer carriage one could control both the coherer and oscillator circuits.

The various parts of the oscillator circuit are shown in Plate I.

The motor and break were enclosed in a double box, the space between the two boxes being packed with felt. This was done in order to deaden the noise of the motor and primary sparking. Such a proceeding is not essential to the good working of the coherer, but it enables one to detect at once by the ear any variation in the secondary sparking. It thus leaves the eyes free to observe the movements of the Mille-Ampère meter needle. One soon became accustomed to the characteristic crackling sound of the kind of sparks required and accordingly hardly ever needed to look at the oscillator. The sparks produced at the oscillator must be continuous and always the same, otherwise the waves set up will differ from each other and consequently the Mille-Ampère meter needle readings will vary so irregularly as to be absolutely worthless. Sparks of the same nature must therefore be produced at all times during the experiment. This is rendered possible by the employment of the continuous stream of water over the surface of the mercury in the mercury cup of the break.

The coherer and its capacity were mounted upon a stand, carried upon a carriage which could be easily moved along a graduated track. It was possible to make a change in position of the carriage as small as .25 mm. To the side of the carriage was firmly secured a shelf which supported the keys of the two circuits, the shunt resistance and the Mille-Ampère-meter. The lower part of the carriage held the battery and its resistance box.

If the coherer be placed in any part of the room, it responds to the sparking of the oscillator, but in some positions more strongly than in others. It thus appeared desirable to place the oscillator within a completely closed metal box, with a window in its front side. This proved beneficial, since it caused the waves to be less scattered at the instant of leaving the oscillator, confining them more to that region of the room where the experiment is conducted, than elsewhere. The metal box then acts, as it were, like a megaphone. The front of the box was on hinges and could be left open at pleasure. The inside of the metal box was put into metal connection with the gas pipes of the room. At one end of the room was placed the oscillator, while at the opposite end was fixed a metal reflector which was connected by wires to gas pipes and

water pipes. In the free space between the oscillator and reflector moved the coherer carriage. The dimensions of free space between the reflector and oscillator were 12·67 m. in length, 6·15 m. in width and 5·14 m. in height. The nearest wall had five windows, each 1·66 m. by 1·12 m. The reflector was of sheet tin 3·32 m. wide by 4·24 m. high.

The oscillator, the coherer globules and the center of the reflector were always kept in the same horizontal line. The oscillator and coherer were thus 2·25 m. above the floor, 2·89 m. below the ceiling and 1·57 m. from the nearest wall, which ran the full length of the room. By moving the carriage to and fro, the coherer was always in the same horizontal line at any desired distance from the reflector.

The coherer carriage was moved to any distance from the reflector, its globules being put into slightest contact, then the coherer circuit was closed by touching the coherer circuit key and the Mille-Ampère meter needle reading taken. Upon touching the key in the oscillator circuit, sparking at the oscillator began, the electric waves traversing the free space act upon the coherer and at once there is or is not an increased reading given by the Mille-Ampère meter needle. By moving the carriage to different distances from the reflector and repeating the above operations different readings are found. There is seen to be a regular increase and decrease in the Mille-Ampère meter needle readings as the coherer is moved farther and farther from the reflector. At certain places no change in the readings is observed, while at certain other places there is a maximum reading. Thus by means of the coherer we are enabled to locate the nodal and antinodal points of the electric waves, and hence we determine the wave-length. Many precautions had to be taken during the conduction of the experiment. The coherer responds to any (secondary) electric spark, the Mille-Ampère meter readings differing for different kinds of sparks. Not only will the coherer respond to the sparks from the oscillator, but it responds to any other (secondary) spark which at the time may have taken place in any other part of the building or on a distant trolley wire. So sensitive is the coherer, the slightest jarring of the room, such as caused by the slamming of a door or of the walking of persons in the corridor, will be sufficient to very materially confuse the readings. Satisfactory and reliable measurements can only be made when such disturbing causes are not present. Accordingly the night hours were selected in which to carry on the observations. If the mercury in the mercury cup of the break becomes coated, the nature of the secondary spark changes and so the readings under such conditions are not proper. If a too strong current be sent up from the storage battery into the

Ruhmkorff coil, the nature of the secondary sparks change so much that the readings must be disregarded. The greatest care had to be exercised to preserve the equality of the oscillator sparks, throughout the whole of the measurements.

It was further noticed, whenever the key of the oscillator circuit was closed (the coherer key being first closed), there was always a very distinct increase in the Mille-Ampère meter readings even before the sparking at the oscillator began. However, as soon as the sparking at the oscillator commenced, this increased reading was augmented more or less according to the distance of the coherer from the reflector. This peculiar motion of the needle before the sparking begins at the oscillator seems to point to an electrostatic effect upon the coherer globules, due to electric or magnetic causes proceeding from the oscillator and preceding those oscillations which give rise to the stationary waves; whatever the cause may be, it has the effect of lessening the resistance between the coherer globules. This phenomenon would appear to throw some light upon the real cause of the action of a coherer. It shows that the metal particles are attracted nearer to each other and there held in contact by the electrostatic effect produced upon them by the passage of the electric waves. Such an effect being different at different distances from the reflector, and most marked near the oscillator, would very much alter the readings as really given by the wires we are endeavoring to measure. Accordingly this effect had to be eliminated. The elimination was thus accomplished. Upon first closing the coherer circuit and allowing the needle to come to rest and then closing the oscillator circuit, the above described phenomenon having taken place, the sparking at the oscillator was continued for a few seconds, causing the needle to creep up to a maximum reading. Then the oscillator circuit was opened and the coherer circuit was opened and closed four or five times in succession; each time the needle returned to the above determined maximum reading. Next the coherer circuit was opened, the oscillator circuit closed, while the sparking was continued for some time, and finally the coherer circuit was closed. The above determined maximum reading of the needle is in all cases (except when the coherer is at a node) augmented, the amount of this augmentation increasing or decreasing as we move away from the reflector towards the oscillator. It is only such waves as the vigorous and prolonged sparking at the oscillator sets up and maintains that are able to increase the first determined maximum reading. Thus the effects of the above observed phenomenon are obviated, since they are powerless to alter the first-determined maximum reading. Such a precaution demanded a great amount of additional time and patience;

nevertheless it successfully eliminated the disturbance, which was very detrimental to the accuracy of the observed readings of the needle. All the measurements herein given were taken by the above method. The readings thus taken are very small, the highest not exceeding three small divisions of the Mille-Ampère meter scale; but they are otherwise perfectly regular, showing a distinct increase and decrease with change of position of the coherer from the reflector. Readings can be taken with a fair degree of rapidity, when all conditions are favorable; as many as forty having been taken in three hours. Measurements were begun as near the reflector as possible and continued towards the oscillator. The first zero reading was located at 1.1500 m. from the reflector and the first maximum at 2.6290 m. from the reflector. The second zero was found to be at 4.1075 m. and the second maximum at 5.5863 m., while the third zero was at 7.0650 m. from the reflector. We, therefore, have a distance of 1.4790 m. between the first anti-node and node, 1.4785 m. between the first node and second anti-node, 1.4788 m. between the second anti-node and second node and 1.4787 m. between the second node and third anti-node. This gives us a distance of 2.9575 m. between the first and second anti-nodes and also 2.9575 m. between the second and third anti-nodes; that is to say, the half wave-length is 2.9575 m., or the wave-length is 5.915 m. Accordingly there should be a node at .3290 m. back of the reflector. No results are here recorded of the observations made nearer to the oscillator than a full wave-length. For as one approaches the oscillator in this distance, though the readings show increases and decreases yet no actual zero reading was located. Moreover in this space, the phenomenon above described was very strongly active and difficult to overcome. The measurements below tabulated were all taken in the space at least a wave length distant from the oscillator. The following are the results of nearly 500 observations. The first column gives the distances of the coherer from the reflector, columns two and three give the readings on the Mille-Ampère meter scale for the first maximum reading and the increased reading, while column three shows the increase in the readings due to the passage of the electric waves. Five measurements at least were taken at each point of observation. Owing to the space all the readings occupy, only a few of them are here given. The general nature of the rest of the readings can be seen from the curve (p. 12).

10 *G. V. Maclean—Velocity of Electric Waves in Air.*

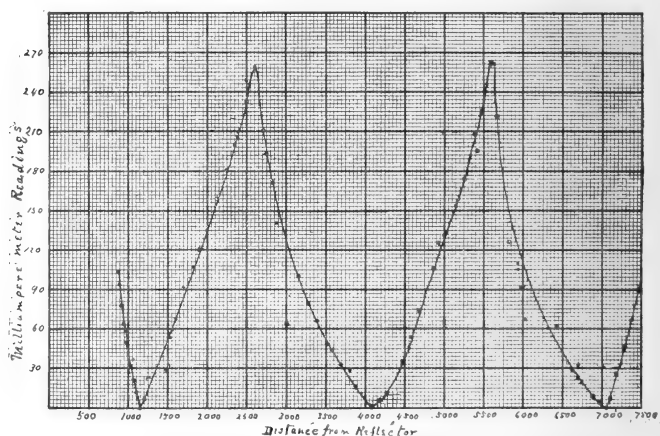
Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
0.9100	8.050	8.125	0.075	
	7.800	7.900	0.100	
	7.900	8.010	0.110	
	7.550	7.650	0.100	
	8.000	8.100	0.100	mean
	8.575	8.650	0.075	0.1035
	7.700	7.825	0.125	
	8.100	8.225	0.125	
	7.950	8.050	0.100	
	7.900	8.025	0.125	
1.1425	5.750	5.750	0.000	
	5.750	5.750	0.000	
	5.600	5.605	0.005	mean
	5.450	5.455	0.005	0.0030
	5.775	5.780	0.005	
1.1500	7.725	7.725	0.000	
	7.400	7.400	0.000	mean (of
First zero or first anti-node	8.450	8.450	0.000	20 results)
	7.450	7.450	0.000	0.0000
	7.850	7.850	0.000	
1.1705	7.160	7.166	0.006	
	7.450	7.450	0.000	
	8.565	8.570	0.005	mean
	8.500	8.509	0.009	0.0040
	8.400	8.400	0.000	
1.2500	8.050	8.060	0.010	mean (of
	8.400	8.410	0.010	5 results)
	8.900	8.910	0.010	0.0100
1.2710	7.700	7.715	0.015	mean (of
	8.065	8.075	0.010	5 results)
				0.0130
2.2500			0.1760	
2.3450			0.1900	
2.4000	The readings are left out, only the means of 5 results given		0.2000	means of
2.4150			0.2050	5 results
2.4745			0.2270	each
2.5000			0.2350	
2.6290	8.300	8.566	0.266	
	7.400	7.630	0.230	mean (of
First node	7.550	7.800	0.250	12 results)
	7.560	7.775	0.275	0.2600
	7.200	7.475	0.275	
2.6800			0.2250	
2.7500			0.1930	
2.7960			0.1800	
2.8860			0.1530	
3.0000			0.1350	
3.0660			0.1200	
3.1960	The readings are left out, only the means of 5 results are given		0.1000	means of
3.2950			0.0780	5 results
3.4000			0.0660	each
3.5110			0.0510	
3.6040			0.0440	
3.7040			0.0340	
3.8050			0.0260	
3.9270			0.0120	

Distances in ms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
4·1075	8·400	8·400	0·000	
	8·750	8·750	0·000	
	8·400	8·400	0·000	mean (of
Second zero or second anti-node	8·500	8·500	0·000	15 results)
	7·600	7·600	0·000	0·0000
	7·400	7·400	0·000	
4·1876			0·0050	
4·2876			0·0120	
4·2880			0·0130	
4·2940			0·0140	
4·3350			0·0150	
4·5056			0·0350	
4·5600			0·0540	
4·6650	The readings are left out, only the means of 5 results are given		0·0740	means of
4·7250			0·0750	5 results
4·8640			0·1060	each
4·9150			0·1140	
5·0000			0·1300	
5·1700			0·1520	
5·2830			0·1720	
5·3285			0·1780	
5·4500			0·1960	
5·5863	8 000	8·233	0·233	
	7·900	8·160	0·260	mean (of
Second	8·000	8·280	0·280	20 results)
node	8·000	8·285	0·285	0·2620
	7·400	7·650	0·250	
5·6215			0·2460	
5·6925			0·2260	
5·8150			0·1250	
6·7000	The readings are left out, only the means of 5 results are given		0·0220	means of
6 7135			0·0200	5 results
6 7140			0·0170	each
6·8850			0·0100	
7·0330			0·0040	
7·0650	7·300	7·300	0·000	
	7·400	7·400	0·000	
	8·850	8 850	0·000	mean (of
Third zero or	8·000	8 000	0·000	25 results)
third anti-node	8·950	8 950	0·000	0·0000
	7·000	7·000	0·000	
7·0660			0·0010	
7·1450	The readings are left out, only the means of 5 results are given		0·0060	means of
7·1775			0·0250	5 results
7·2945			0·0450	each
7·5000			0·0800	

The means of each of these sets of five readings are taken and plotted as a curve, the coördinates of whose points are the distances of the coherer from the reflector and these mean values. The resulting curve is given in fig. 1.

The velocity of the electric waves was determined from the formula $\lambda = VT = 2\pi V\sqrt{LC}$ where λ is the wave-length, L the self-induction, C the capacity, V the velocity and T the time of oscillation of the secondary spark. T was found by the photographic process. The sparks directly given by the oscillator used in the original experiment could not be photographed. They were too small and, moreover, their light was not actinic enough. Sparks given by similar capacity and self-induction but of larger dimensions and cadmium points in place of the platinum globules were photographed. The self-induction here used consisted of two parallel

1.



copper wires of the same diameter as were employed in the original experiment, 5 cm. apart and 1051.1 cm. in length. The capacity was the same glass plate with the tin foil sheets four times as large. The time of oscillation of the sparks thus produced was found to be $4.12382 \times 10^{-7} = T'$ seconds. It was then assumed, that the formula must still hold good if we cut down the self-induction and capacity, still keeping the copper wires 5 cm. apart. That is to say, if we make our C one-fourth and our L $\frac{1}{100}$ th of the L used in the photographic process the time of oscillation of our spark will be $\frac{1}{20}$ th of that of the spark photographed. In the original experiment the area of the tin foil was just one-fourth of that on the condenser which formed the capacity for the spark photographed, whereas the length of copper wire was 9.62 cms, being $\frac{9.62}{1051.1}$ of what was used in the photographic process. Accordingly

the time oscillation of our spark would be 1.976×10^{-8} secs. This is then the value of T . We have already found λ , the wave-length, to be 591.5 cms. And since $\lambda = VT \therefore V$ the velocity of the electric wave $= \frac{\lambda}{T} = \frac{591.5}{1.976 \times 10^{-8}} = 2.998 \times 10^{10}$ centimeters per second or about 186,365 miles per second.

Professor Trowbridge and Dr. Duane in 1895 found the velocity of electric waves along wires to be 2.996×10^{10} cms, though the mean of seven of their results gave the velocity to be 3.0024×10^{10} cms. per second. To make sure the coherer and oscillator were in tune with each other, the capacity of the oscillator was altered by doubling the area of the tin foil sheets on the glass plate. Sparking at the oscillator was again begun and readings taken whereby it was seen the positions of the original nodal and anti-nodal points were changed. The same thing took place upon altering the self-induction. Also separately the self-induction and capacity of the coherer were altered, with a similar change in the position of the original nodal and anti-nodal points. When the wave-length had been determined it seemed desirable to test the truth of the theory of Poincaré and Bjerknæs. It is a known fact in the photography of electric oscillation, that it is possible to damp out all the oscillations except the fundamental by replacing part of the self-induction by a self-induction having a higher resistance. As, for example, interchanging a length of copper wire by the same length of graphite. Accordingly a cylinder of graphite 5 cms. long was ground down till it had the same diameter of the copper wire it was to replace. The ends of this rod of graphite were next electroplated with copper. Five cms. of one of the copper wires forming the self-induction of the coherer were cut out and replaced by soldering in the prepared graphite. The coherer and oscillator circuits had now the same capacity and self-induction as before, only the resistance of the self-induction of the coherer circuit had been increased. The resistance of the graphite was 12 ohms. Work was now undertaken under these new conditions, with the result that the fifty observations thus made were identical with those taken under the original conditions. The following table gives the measurement taken when the graphite was in the circuit.

14 *G. V. Maclean—Velocity of Electric Waves in Air.*

Distance in cms. from the reflector.	First maximum reading.	Increased maximum reading.	The increase due to the electric waves.	
1·1500	8·100	8·100	0·000	
	8·550	8·550	0·000	
	8·450	8·450	0·000	mean
	6·450	6·450	0·000	0·0000
	8·250	8·250	0·000	
2·6290	8·600	8·825	0·225	
	8·000	8·250	0·250	
	7·600	7·850	0·250	mean
	7·800	8·100	0·300	0·2600
	8·550	8·825	0·275	
2·7960	8·150	8·325	0·175	
	7·400	7·565	0·165	
	7·450	7·650	0·200	mean
	6·475	6·650	0·175	0·1800
	8·000	8·185	0·185	
3·1960	7·800	7·900	0·100	
	7·750	7·850	0·100	
	7·250	7·400	0·125	mean
	8·425	8·500	0·075	0·1000
	8·400	8·500	0·100	
4·1075	8·750	8·750	0·000	
	8·350	8·350	0·000	
	7·100	7·100	0·000	mean
	8·300	8·300	0·000	0·0000
	8·400	8·400	0·000	
3·4000	8·800	8·850	0·050	
	8·425	8·500	0·075	
	8·400	8·466	0·066	mean
	8·500	8·575	0·075	0·0660
	8·100	8·165	0·065	
4·5056	8·150	8·175	0·025	
	7·750	7·800	0·050	
	8·350	8·400	0·050	mean
	8·575	8·600	0·025	0·0375
	8·300	8·350 ?	0·050 ?	
	7·835	7·860	0·025	
5·5863	8·400	8·625	0·225	
	8·450	8·700	0·250	
	8·150	8·450	0·300	mean
	8·500	8·750	0·250	0·2620
	8·450	8·735	0·285	
6·6670	8·250	8·300	0·050	
	8·400	8·425	0·025	
	8·500	8·525	0·025	mean
	8·100	8·150	0·050	0·0350
	8·550	8·575	0·025	
7·0650	8·950	8·950	0·000	
	8·800	8·800	0·000	
	8·650	8·650	0·000	
	8·600	8·600	0·000	
	8·800	8·800	0·000	mean
	7·350	7·350	0·000	0·0000
	7·450	7·450	0·000	
	7·600	7·600	0·000	
	7·845	7·845	0·000	
	8·000	8·000	0·000	

This latter experiment shows that the wave-length we have measured was that of the fundamental wave. And, moreover, that by the use of this particular coherer or the electro-bolometer, the balancing of the self-inductions and capacities and by our method of operating the oscillator, all the electric waves in the number of different waves proceeding from the Ruhmkorff coil, except the fundamental, had been completely damped. If such had not been the case, it is very evident the measurement so taken would not have been identical with those first observed.

The experiment was pushed further. The new self-induction (graphite) of the coherer circuit being retained, the capacity of the oscillator circuit was made double of what it was in the original case and, therefore, double of that now in the coherer circuit. At those points where the original readings indicated nodes and anti-nodes the readings were now changed. The following table shows some of the changes.

The new self-induction in the coherer circuit and the original capacity in the oscillator circuit.		The new self-induction in the coherer circuit and the capacity in the oscillator circuit, doubled.	
Distance in ms. of the coherer from the reflector.	Difference between the maximum and increased maximum readings of the m-a-m.	Difference between the maximum and increased maximum readings of the m-a-m.	
1.1500	0.000	0.075	
2.6288	0.260	0.275	
4.1075	0.000	0.150	
5.5863	0.262	0.250	
7.0650	0.000	0.081	
	(average of 5 readings)	(average of 5 readings)	

Similar changes took place at other points.

Next the capacity of the coherer circuit was altered and as a consequence, at those points where the original readings were taken, the readings now were different. Finally the capacity (i. e. the tinfoil plates) of the coherer circuit was left out entirely and so also was the self-induction, for at this stage of the experiment the graphite broke. The readings were now of all sorts, the needle moving very capriciously, whenever the sparking began or continued at the oscillator. No regular increase and decrease in the readings could be determined, as the coherer was moved farther and farther from the reflector. At one time the needle would be deflected four or five whole divisions of the Mille-Ampère meter scale while in the next second, at the same place, there would be only a displacement of the needle of .2 or .3 of a division in the forward direction or else a deflection in the opposite direction, and even at times the needle trembled as if acted upon by almost equally opposing influences. These irregular motions of the needle made a great contrast with the regular motions when the coherer and

oscillator were in tune. This experiment confirms the truth of the damping theory of Poincaré and Bjerknes.

Sarasin and de la Rive's theory of a multiplicity of waves of different amplitudes originating at the same oscillator was substantiated by the erratic readings obtained when the coherer proper alone was employed. In fact the truth of their theory was readily seen when the ordinary metal filings coherer or Branly tube was used, since the irregularity of the readings was evidently such as would be produced by quickly succeeding waves of different kinds acting upon the tube. The point which might be the position of a node due to one wave would be the anti-node or at least not always the node due to the next following wave.

I desire here to express my gratitude to Professor Trowbridge for his valuable suggestions, his assistance and his very great kindness in placing at my disposal the resources of the Physical Laboratory in order to have this experiment carried to a successful completion.

Jefferson Physical Laboratory, Harvard University,
Cambridge, Mass., April, 1899.

ART. II.—*A Spiral Fulgurite from Wisconsin*; by
WILLIAM H. HOBBS.

THERE has recently been presented to the geological collection of the University of Wisconsin a lightning tube or fulgurite which has considerable interest because of its shape—a perfect dextro-rotary helix. The specimen is the gift of Mr. G. H. Kruschke, town clerk of the town of Cutler, Wisconsin, who has furnished me with the data for the following description of the manner of its discovery.

The fulgurite was discovered in October, 1897, by Frank de Lap, Mr. Kruschke's son-in-law, while digging a cellar on the southeast quarter of the northeast quarter of Sec. 20, T. 18, R. 2 E., Town of Cutler, Juneau County, Wisconsin. It was imbedded in a sand knoll about ten feet high, at a distance of five feet below the surface. A house has since been built upon the spot.

A sample of the sand in which the tube was found has been kindly furnished by Mr. Kruschke, and proves on examination to be a fairly clean sand, of a light brown color, largely composed of translucent quartz grains which average about $\frac{1}{64}$ th of an inch in diameter. The coloring matter appears to be ferric oxide. The tube itself is about as thick as a man's thumb, and over five inches long. When found it was about three inches longer, but Mr. Kruschke reports that a piece was accidentally broken off and lost. Examination of the broken end shows that the fulgurite is composed of a dull gray slaggy mass, filled with larger and smaller cavities exactly like those observed in porous natural slags. There are a few dark specks surrounded by stains of iron oxide. Somewhat excentrically located in this end section is a cavity of irregular cross-section which appears to extend into the fulgurite as a more or less continuous tube, but is so bent and locally contracted that it is impossible to follow it for any distance. Its average diameter is about $\frac{3}{16}$ th of an inch, but it is partly filled by blister-like eruptions which protrude from its walls. One of these blisters which is broken open has walls as thin as paper.

The other end of the fulgurite has not been broken in any way but forms four irregular horn-like projections (*a-a* in the left of fig. 1). The channel (it cannot be asserted that this is continuous with the one observed at the other end) emerges at one side of the fulgurite (*a*, in right hand portion of fig. 1) with only a thin wall less than a millimeter in thickness on the outer side.

The surface of the fulgurite is very irregular, being traversed by corrugations whose greatest extension is in the direction of the longer axis of the fulgurite, though they exhibit some tendency to wrap themselves around it in a dextro-rotary manner. These corrugations appear to be, for the most part, thin-walled tubes (*b*, at the left in fig. 1) which are not now con-

1.

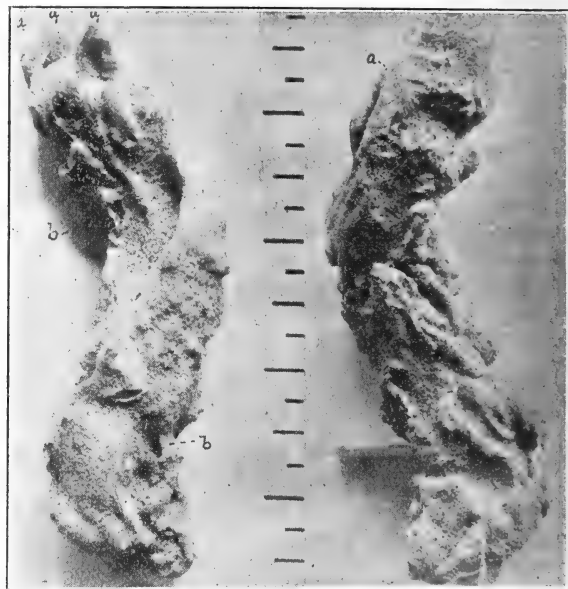


FIG. 1. Spiral fulgurite from Cutler, Wisconsin, showing opposite sides. The units in the scale are inches. *a*, *a*, *a*, in the figure at the left, horn-like protuberances terminating the fulgurite. *b* of the same portion of the figure, corrugations broken open and exhibiting thin-walled tubes. *a* in figure at the right, point of emergence of main channel (hidden in the view).

tinuous passages, but are so distorted and contracted locally as to suggest that they have suffered collapse since their formation.

Over the entire outer surface of the fulgurite are grains of sand which show varying degrees of former fusion. Those which have been completely fused are opaque and white, and are firmly cemented to the glass of the tube. The others adhere less firmly and where distributed abundantly appear brown, as in the sample of loose sand from the locality. The photographs shown in fig. 1 exhibit opposite sides of the fulgurite and indicate, as well as any photographs are likely to do, its perfectly helical form. The only fulgurite known to me

which shows any approach to this shape is that from Waterville, Maine, described by Bayley,* which has marked corrugations that wind about the axis of the fulgurite in the form of a dextro-rotary helix.

The fact that the Waterville and Cutler fulgurites show each a spiral twist of the same type is sufficient evidence that the

2.

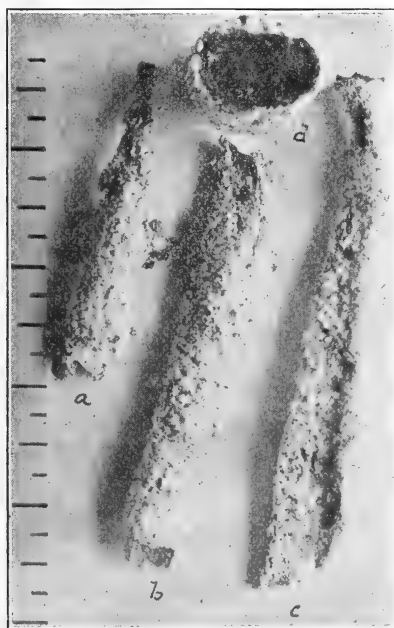


FIG. 2. Artificial fulgurites made by Prof. Wood. The units in the scale are inches. *a* is a tube with branch-like protuberance at the side. *b* is a tube of nearly symmetrical cross-section. *c* is a tube with marked corrugation extending along one side. *d* exhibits the cross-section of a large tube.

structure is not an accidental one, but one to be explained by the conditions of the lightning discharge, which doubtless followed a spiral course through the sand. Professor R. W. Wood, of the Physical Department of the University of Wisconsin, has suggested to me that this may be explained in some way by the influence of the earth's magnetic field upon the discharge. There is at least a possibility that there may be some analogy between the experiments of Hittorf† with electric

* A Fulgurite from Waterville, Maine, by W. S. Bayley, this Journal (3), 1892, xliii, p. 327.

† J. J. Thomson, Recent Researches in Electricity and Magnetism. Oxford, 1893, p. 134.

discharges in a magnetic field, and the lightning discharge. Hittorf found that in the case of negative discharge in a direction nearly parallel to a line of force that the spark takes the form of a dextro-rotary spiral and wraps itself about the line of force. It hardly seems possible that the earth's field would be sufficiently strong to effect such a change in the course of the lightning, and, moreover, the return discharge would be of an opposite character, and should produce a spiral of the opposite kind unless the initial discharge controls the form of the sand tube. The above is, therefore, offered only as a suggestion and not in any sense as an adequate explanation.

I do not remember to have seen any description of artificial fulgurites. Professor Wood, on being shown the Cutler fulgurite, expressed the belief that he could make some of the ordinary kind. Within a half hour he had produced the tubes which are shown in fig. 2, by immersing carbon electrodes in a bath of sand and passing the current from an ordinary arc circuit through them. In *a* of the figure is seen a fulgurite having a hollow protuberance on one side—really a branch of the tube; *b* is a tube of fairly symmetrical cross section; the tube *c* has a marked corrugation extending along one side, and shows perhaps a slight trace of spiral curving; while *d* (shown in cross section) indicates how large fulgurites may be made by this simple method. I am indebted to Professor Wood for permission to publish a photograph of these artificial fulgurites.

University of Wisconsin.

ART. III.—*On the Chemical Composition of Parisite and a new occurrence of it in Ravalli Co., Montana*; by S. L. PENFIELD and C. H. WARREN.

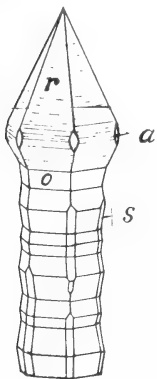
RECENTLY Mr. Lazard Cahn of New York sent to the Mineralogical Laboratory of the Sheffield Scientific School for identification, several specimens from Montana, showing crystals of an unusual appearance. These proved to be the rare mineral parisite, hitherto observed only in small amount at the original locality, the emerald mines of the Muso Valley, United States of Columbia; sparingly at Ober Arö, Langesundfiord, Norway;* and quite recently the mineral has been found at Narsásuk in Southern Greenland. A brief note on its occurrence at the latter locality was made by Gust. Flink in the report of a trip made there during the summer of 1897.

Not only does a new occurrence of parisite and the peculiar habit of the crystals deserve notice, but the chemical composition of the mineral has never been determined with certainty, and, therefore, analyses have been made for the purpose of determining this important character. It is with pleasure that we express to Mr. Cahn our thanks for a generous supply of the material from Montana for analysis.

The parisite crystals from Montana are supposed to have come from near Pyrites, Ravalli County, and occur in a fine-grained, loosely coherent, white material, which can be readily crushed to a powder with the finger nail. The matrix consists essentially of silica, alumina, calcium and a little alkali, and has the appearance of a decomposed rhyolite or trachyte, but its exact nature has not been more definitely determined. Through this white material crystals of pyrite and parisite are scattered, generally isolated, but at times the parisite has grown over and partly or completely surrounded the pyrite crystals. The pyrite is crystallized in pyritohedrons modified by small faces of the cube and octahedron, and the crystals vary in size from microscopic up to 3^{mm} in diameter. The average size of the parisite crystals is about 1^{mm} in diameter by 10^{mm} in length. They are quite numerous, so that from four to ten individuals may be seen on a surface of ten square centimeters of the matrix. The habit which they generally present is that of a horizontally striated hexagonal shaft, made up of steep pyramids in oscillatory combination and terminated at the ends by distinct, somewhat enlarged pyramids. The accompanying figure, which represents a portion of the shaft and one termination, gives a fair idea of the development of the crystals. The faces which are most prominent in forming the shaft are those of the pyramid *o* (2021) in oscillatory combination. Measurements over the reëntrant and salient angles

* Brögger, Zeitschr. Kr., xvi, 650, 1890.

could be made with the reflecting goniometer and are given in an accompanying table. Some of the edges of the pyramid *o* are truncated by a pyramid of the second order *s* ($11\bar{2}1$), also in oscillatory combination, but, as shown in the figure, this form generally is not continuous throughout the whole length of the shaft nor is it present on all the edges. The pyramid which finally terminates the crystals is *r* ($20\bar{2}3$). This is generally quite distinct, although its middle edges are somewhat rounded by a system of fine horizontal striations. The prism of the second order *a* ($11\bar{2}0$), represented in the figure, is always small and frequently wanting. The prism of the first order, *m* ($10\bar{1}0$), was not observed as a distinct face, although the oscillatory combination of the upper and lower pyramidal faces often gave rise to striated, rounded, surfaces which approximate in position to the faces of this prism. Occasionally the shafts taper to a point without the enlarged pyramid. Of the forms observed, *a* ($11\bar{2}0$), *r* ($20\bar{2}3$), *o* ($20\bar{2}1$), *s* ($11\bar{2}1$) and *m*? ($10\bar{1}0$), the prism *a* is new. The angles which were measured are given below, together with the values calculated from the vertical axis established by Des Cloizeaux,* $c = 3.2891$.



	Measured.	Calculated.
$a \wedge a = 11\bar{2}0 \wedge 1\bar{2}10 =$	$59^{\circ} 54'$	$60^{\circ} 00'$
$r \wedge r = 20\bar{2}3 \wedge 02\bar{2}3 =$	55 25	$55^{\circ} 25\frac{1}{2}$
$r \wedge r = 20\bar{2}3 \wedge \bar{2}023 =$	137 22	136 54
$s \wedge s = 11\bar{2}1 \wedge 11\bar{2}\bar{1} =$	17 23	17 18
$o \wedge o = 20\bar{2}1 \wedge 20\bar{2}\bar{1} =$	13 10	14 00

For the chemical analysis the best material that could be obtained was secured by picking out the crystals from the matrix by hand, and rubbing them between the fingers to remove any loosely adhering material. The crystals enclosed, as has been said, a little pyrite and were not very firm, consequently some siliceous material was deposited in the cracks. These impurities amount to about six per cent. The material was of a nearly uniform yellowish brown color.

The method of analysis was as follows: Carbon dioxide was obtained by dissolving the mineral in hydrochloric acid and collecting the gas evolved in weighed potash bulbs. For fluorine, another portion of material was fused with sodium carbonate and a weighed amount of silica, and the fluorine separated and estimated by the Berzelius method as modified by Penfield and Minor.† The earths were separated from calcium by repeated precipitations with ammonia, and they were then converted into oxalates, ignited, and weighed as

* Min., ii, p. 162, 1874.

† This Journal, III, xlvii, p. 387, 1894.

oxides. The amount of cerium oxide, Ce_2O_3 , was estimated by decomposing the ignited oxides (CeO_2 , La_2O_3 and Di_2O_3) with sulphuric acid, to which some oxalic acid was added, and weighing the carbon dioxide liberated by the higher oxide of cerium, according to the equation, $2\text{CeO}_2 + \text{H}_2\text{C}_2\text{O}_4 = \text{Ce}_2\text{O}_3 + 2\text{CO}_2 + \text{H}_2\text{O}$. The joint molecular weight of the cerium, lanthanum, and didymium oxides ($\text{Ce, La, Di}_2\text{O}_3$) was estimated by converting a weighed quantity of the oxides into sulphates and was found to be 328.2. The results of the analyses are given beyond.

As the considerable amount of impurities in the Montana parisite rendered the calculation of the formula somewhat uncertain, an analysis of the mineral from Muso Valley was also made. Exceptionally pure material for this analysis was obtained from a fragment of a large crystal in the Brush collection. In this analysis it was found that the full amount of fluorine was not obtained by a single fusion with sodium carbonate and silica, and soaking out with water. By saving the residues and fusing them a second time with sodium carbonate and a slight addition of silica, about 0.5 per cent of fluorine was obtained. This precaution was not taken in the analysis of the Montana mineral and consequently the ratio of the fluorine in that analysis is a little low. The joint molecular weight of the cerium, lanthanum and didymium oxides was found to be 328.4. The results of the analyses are given below, together with the analysis by Damour and Deville* of the parisite from Muso.

	I. Warren. Montana.		II. Warren. Muso.		III. Damour and Deville. Muso.	
		Ratio.		Ratio.		Ratio.
Specific gravity,	4.128		4.302		4.358	
CO_2 -----	22.93	.521	24.22	.550	23.48	.533
F -----	5.90	.310	6.82	.359	5.55	.292
Ce_2O_3 -----	26.14	.166	30.67	.183	44.21	.187
(La, Di) $_2\text{O}_3$ -----	28.46		29.74		18.00	
CaO -----	10.98	.196	10.70	.191	10.10	.180
<hr/>						
Fe_2O_3 (pyrite ?) .	.80		.20		101.34	
Na_2O -----	.69		.20		0 = 2F = 2.34	
<hr/>						
K_2O -----	.19		.10		99.00	
<hr/>						
H_2O -----	.26		102.65			
Gangue by } difference. }	6.13	0 = 2F = 2.87				
<hr/>						
0 = 2F -----	2.48		99.78			
<hr/>						
	100.00					

* C. R., lix, p. 270, 1864.

The ratios derived from the foregoing analyses are as follows :

	CO ₂ :	F :	(Ce, La, Di) ₂ O ₃ :	CaO
I.	·521	·310	·166	·196 = 3·00 : 1·79 : 0·96 : 1·13
II.	·550	·359	·183	·191 = 3·00 : 1·96 : 1·01 : 1·04
III.	·533	·292	·187	·180 = 3·00 : 1·65 : 1·05 : 1·01

The new analysis of the exceptionally pure material from Muso Valley gives a ratio approximating very close to 3:2:1:1. The material from Montana is not so pure, consequently the ratio is less satisfactory. The fluorine in the mineral doubtless caused some of the gangue material to go into solution, thus causing the calcium to be a little high; while the fluorine is evidently low, because, as previously stated, the precaution was not taken to repeat the fusion with sodium carbonate and silica in estimating that constituent. The ratio obtained by Damour and Deville agrees with those obtained from the new analyses except as regards fluorine. It is believed, however, that their method of estimating fluorine is open to criticism, since they made no direct determination of this element but, assuming that on dissolving the mineral in very dilute hydrochloric acid the fluorine separated out completely as the fluorides of calcium and cerium, they ascertained the weight of these fluorides, and considered fluorine as equal to the difference between this weight and that of the calcium and cerium derived from an analysis of the insoluble residue.

Excepting the defects in the analyses, evidently due to failures in estimating fluorine correctly, the ratios derived from the three analyses indicate conclusively that CO₂, F, (Ce, La, Di)₂O₃ and CaO are united in the proportion of 3:2:1:1. Representing the trivalent metals of the cerium group collectively by R, it is probable that fluorine is directly united with them to form a bivalent radical (RF), and that parisite is a double carbonate, 2(RF)CO₃ + CaCO₃, or (RF)₂Ca(CO₃)₃.

As far as the proportions of the different constituents is concerned, either of the foregoing expressions is equivalent to the formula proposed by Groth† (CaF)(CeF)²Ce(CO₃)₃. Groth based his formula upon the single analysis of Damour and Deville, previously cited, and was correct in assuming that the deficiency in fluorine was due to a failure to estimate that constituent correctly. It seems to us more reasonable to consider the fluorine as playing a single role, united with the Ce, La, and Di metals to form a bivalent radical (RF), than to adopt the formula of Groth where fluorine plays a double role, united with calcium to form a univalent radical (CaF) and with cerium to form a bivalent radical (CeF).

* Tabellarische Uebersicht der Mineralien, 1898, p. 61.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1899.

ART. IV.—*The Estimation of Iron in the Ferric State by Reduction with Sodium Thiosulphate and Titration with Iodine*; by JOHN T. NORTON, JR.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIII.]

THE action of sodium thiosulphate on ferric iron has long been known and depends upon the following reaction :



As early as 1859 Sherer* proposed a method for the estimation of ferric iron depending on the above reaction. Sherer's method of procedure was to act upon a solution of ferric chloride with sodium thiosulphate until the purple color produced by the interaction of these two salts just vanished. Mohr's† experimental tests of this process were not successful. A year or two later Kremer and Landolt,‡ after a careful investigation of Sherer's process, recommended it with the modification that any free hydrochloric acid present should be neutralized by sodium acetate until the solution assumed a red color, just enough hydrochloric acid added to destroy this red color, and sodium thiosulphate run into the solution in slight excess. When the liquid became perfectly colorless and gave no reaction for ferric iron with potassium sulphocyanide, the excess of sodium thiosulphate was titrated back with iodine and starch. The authors also state that the ferric iron should not be present in concentrated solution. Very good results were claimed for this process, but it apparently gained but slight recognition.

Oudemans,§ who was the next to study the action of ferric iron and sodium thiosulphate, claimed that the addition of a small quantity of cupric salt to the iron solution hastened the reducing action of the sodium thiosulphate. Mohr,|| however, condemned this method also as unreliable, both because the sodium thiosulphate acted upon the copper as well as the iron and also because the potassium sulphocyanide, added as an indicator of the completeness of the reduction, produced a precipitate of cupric sulphocyanide which interfered with the reaction. In a second paper Oudemans¶ reiterated his former statement as to the accuracy of his method but advised the use of a smaller quantity of the cupric salt. An improvement on Oudemans' process was proposed by Haswell,** who mixed

* Gelehrte Anzeigen der könig. Bayrisch. Acad. vom Aug. 31, 1859.

† Anal. d. Chem. u. Pharm., cxiii, 260.

‡ Zeitschr. f. Anal. Chem., i, 214.

§ Zeitschr. f. Anal. Chem., vi, 129.

|| Titrimethode

¶ Zeitschr. f. Anal. Chem., ix, 362.

** Repertorium der Analytischen Chem., i, 179.

the moderately acid solution of ferric chloride in the presence of a cupric salt with a few drops of sodium salicylate and then reduced with sodium thiosulphate previously standardized upon a known quantity of iron by the same process and estimated the excess by potassium dichromate. Bruel* modified this process by operating without the copper solution, relying merely on the discharge of the violet color in a boiling solution by sodium thiosulphate standardized on a ferric solution of known strength.

Although considerable work has been done on the reaction between ferric iron and sodium thiosulphate, no process depending upon this reaction has obtained acceptance. In view, therefore, of previous work on the action of hydrochloric acid upon sodium thiosulphate† and with the idea that a careful control of the dilution and quantity of acid present might greatly better the accuracy of the method, it has seemed to me to be desirable to study this process again in detail.

The ferric oxide employed in the experiments was prepared with great care by the ignition of ferrous oxalate obtained by acting with oxalic acid on pure ammonium ferrous sulphate. To ascertain, however, if this oxide contained any impurity, about 0.5 of a gram. was put into a porcelain boat and submitted to the action of a current of hydrochloric acid gas and chlorine at a temperature of about 280° C. (according to a process recently described from this laboratory‡) until all the ferric salt is volatilized in the form of ferric chloride. A residue of 0.0010 gram. for every 0.5 of a gram. of the oxide was found, and this correction, small for the amounts generally used, has been applied in the following determinations. The sodium thiosulphate used was taken in nearly $\frac{n}{10}$ solution and was standardized against an approximately decinormal solution of iodine which had been determined by comparison with decinormal arsenious acid made from carefully resublimed arsenious oxide.

In those experiments which deal with amounts of ferric oxide not exceeding 0.2 of a gram., measured portions of a solution of ferric chloride made of known strength by dissolving about 2 grms. of the pure carefully weighed ferric oxide in 20^{cm}³ of strong hydrochloric acid and diluting to one liter, were drawn from a burette. In the case of the larger quantities of ferric oxide the salt was weighed out, dissolved in hydrochloric acid and brought to the required dilution. The ferric chloride, either drawn from the burette or prepared directly from the weighed oxide, was diluted with water, a drop of potassium

* Compt. Rendus, xcvi, 954.

† This Journal, vol. vii, 287.

‡ Gooch and Havens, this Journal,

sulphocyanide added to serve as an indicator and an excess of sodium thiosulphate was run in until, after standing for a few minutes, the solution became perfectly colorless, and the excess of sodium thiosulphate was then titrated back with decinormal iodine after the addition of starch.

Several sources of error are, plainly, possible in the process: incompleteness in the reduction of the ferric salt; decomposition of the thiosulphate by the acid, resulting in the subsequent over-run of iodine; the possible tendency of the ferric salt under concentration to oxidize the thiosulphate to the condition of the sulphate rather than to that of the tetrathionate; and finally the oxidizing action of the air, which may tend to keep up progressive oxidation of the iron salt and excessive expenditures of thiosulphate. The first three sources of difficulty tend to produce errors of deficiency; the fourth an error of excess.

The first step in the experimental study of the process was to determine the effect of varying dilution upon the estimation of a given quantity of iron reduced by sodium thiosulphate, taken in practically uniform excess above the amount theoretically required, in the presence of 1^{cm³} of hydrochloric acid.

TABLE I.

	Fe ₂ O ₃ taken. grms.	Fe ₂ O ₃ corrected. grms.	Dilution. cm ³ .	HCl. cm ³	Na ₂ S ₂ O ₃ in excess. cm ³ .	Fe ₂ O ₃ found. grms.	Error. grms.
1.	·1000	·0998	100	1	18·08	·0957	·0041—
2.	·1000	·0998	200	1	20	·0966	·0032—
3.	·1000	·0998	300	1	17·56	·0995	·0003—
4.	·1000	·0998	400	1	17·16	·0998	·0000
5.	·1000	·0998	600	1	17·76	·0996	·0002—
6.	·1000	·0998	800	1	17·65	·0993	·0005—
7.	·1000	·0998	1000	1	18·02	·0988	·0010—
8.	·1000	·0998	1200	1	17·95	·0977	·0021—
9.	·1000	·0998	1400	1	17·99	·0965	·0033—
10.	·1000	·0998	1600	1	18·01	·0947	·0051—
11.	·2001	·1997	400	2	27·05	·2029	·0032+
12.	·2001	·1997	800	2	15·95	·1998	·0001+
13.	·4998	·4988	1000	2	22·36	·5104	·0126+
14.	·5051	·5041	1800	4	15·27	·5026	·0017—
15.	·4002	·3994	1500	4	27·29	·3996	·0002+
16.	·7502	·7487	1000	1	9·73	·7572	·0085+
17.	·7029	·7015	2000	4	12·67	·7004	·0011—

This table shows plainly that with quantities of ferric oxide present up to 0·1 gm. the dilution can vary from 400^{cm³} to 1000^{cm³} for each cm³ of strong hydrochloric acid and still give excellent results. At a dilution greater than 1000^{cm³} the action of the thiosulphate is evidently incomplete, and at a

smaller dilution than 400cm^3 the decomposing action of the acid on the thiosulphate becomes noticeable. When larger quantities of iron oxide are dealt with, it appears that the dilution ought to be increased proportionally with the quantity of ferric oxide present as well as with that of the acid. This is illustrated in experiments 9-15 of the table. On this account it seems necessary, assuming that the quantity of acid present is always kept within the maximum strength mentioned, 1cm^3 to 400cm^3 , to regulate the dilution from the approximate quantity of the iron so that not less than 400cm^3 of water shall be used to every 0.1 gram. of iron oxide present. Under properly regulated conditions of dilution as regards acid and the iron salt, the reduction is completed in from five to ten minutes.

Great excesses of acid, however, contrary to the statement of Kremer,* retard the reduction greatly, and, in spite of the tendency of the thiosulphate to decomposition and the production of errors of deficiency under such circumstances, plus errors due to partial oxidation come to light. This fact appears in the following table, which records the results of processes lasting many hours.

TABLE II.

	Fe_2O_3 taken. grms.	Fe_2O_3 corrected. grms.	Dilution. cm^3 .	HCl. cm^3 .	$\text{Na}_2\text{S}_2\text{O}_3$ in excess. cm^3 .	Fe_2O_3 found. grms.	Error. grms.
18.	·5012	·5002	1700	10	25·99	5308	·0306 +
19.	·7512	·7497	1200	15	57·8	7685	·0188 +
20.	·7520	·7505	2000	15	56·4	7983	·0478 +
21.	·7520	·7505	1700	15	27·2	7627	·0122 +

As to the temperature at which the reduction should be made, my experience, contrary to that of Kremer, goes to show that no elevation above atmospheric conditions is necessary; under the conditions of acidity and dilution laid down, the process of reduction is complete within ten minutes after the introduction of the thiosulphate; moreover, former experience† shows clearly the danger of submitting mixtures of sodium thiosulphate and acid to temperatures much above the ordinary. On the other hand, artificial reduction of temperature tends to retard the action to an impossible degree. Thus, in an experiment it took five minutes to reduce 0.0500 of ferric oxide at 21°C . completely at a dilution of 200cm^3 and in the presence of $\frac{1}{2}\text{cm}^3$ of hydrochloric acid; under conditions otherwise precisely similar excepting that the temperature was lowered to 0°C ., the action lingered forty-five minutes.

* Zeit. f. Anal. Chem., i, 214.

† This Journal, vol. vii, 287.

Lastly, the question as to the excess of thiosulphate necessary to complete the reduction within a reasonable time must be considered. In nearly all previously recorded experiments the excess of thiosulphate was not less than 15cm^3 of the $\frac{n}{10}$ solution. The following table shows the effect of diminishing this excess.

TABLE III.

	Fe ₂ O ₃ taken. grms.	Fe ₂ O ₃ corrected. grms.	Dilution. cm ³ .	HCl. cm ³ .	Na ₂ S ₂ O ₃ in excess. cm ³ .	Fe ₂ O ₃ found. grms.	Error. grms.
22.	·0250	·0250	400	$\frac{1}{4}$	12·2	·0241	·0009—
23.	·0500	·0499	400	$\frac{1}{2}$	12·2	·0495	·0004—
24.	·0500	·0499	400	$\frac{1}{2}$	13·66	·0493	·0006—
25.	·1000	·0998	400	1	7·31	·0984	·0014—
26.	·1000	·0998	400	1	7·63	·0972	·0026—
27.	·1001	·0999	400	1	12·88	·1007	·0008+
28.	·1498	·1495	600	$1\frac{1}{2}$	11·97	·1475	·0020—
29.	·1996	·1992	800	2	12·43	·1980	·0012—

From the above experiments taken in connection with those of Table I it is clear that there should always be present an excess of at least 15cm^3 of the $\frac{n}{10}$ solution of sodium thiosulphate. If the quantity of hydrochloric acid is kept very low there is no reason why this excess of thiosulphate could not be considerable without producing any disturbing effect. Practically, however, the presence of an excess between the limits of 15cm^3 and 35cm^3 of the $\frac{n}{10}$ solution has been found to give the most satisfactory results.

To recapitulate then, it has been shown that the dilution must be at least 400cm^3 for each ·1 of a gram. of iron oxide present, that the quantity of acid should never exceed 1cm^3 of the strong acid to each 400cm^3 of water, that the time of reduction must be short to avoid progressive oxidation, that the temperature of the solution should be kept at the normal temperature of the atmosphere, and finally that the excess of sodium thiosulphate present should never be less than 15cm^3 of the $\frac{n}{10}$ solution. In the case of large dilution the use of freshly boiled water is recommended so as to avoid the reoxidizing effect of the air upon the reduced iron. In the experiments included in the following table, the above precautions were closely adhered to and manifestly satisfactory results were obtained.

TABLE IV.

	Fe ₂ O ₃ taken. grms.	Fe ₂ O ₃ corrected. grms.	Dilu- tion. cm ³ .	HCl. cm ³ .	Excess Na ₂ S ₂ O ₃ . cm ³ .	Fe ₂ O ₃ found. grms.	Error. grms.
30.	·0125	·0125	200	$\frac{1}{8}$	23·5	·0125	·0000
31.	·0250	·0250	400	$\frac{1}{4}$	21·98	·0250	·0000
32.	·0250	·0250	400	$\frac{1}{4}$	17·	·0250	·0000
33.	·0250	·0250	400	$\frac{1}{4}$	17·	·0250	·0000
34.	·0500	·0499	400	$\frac{1}{2}$	24·	·0498	·0001—
35.	·0500	·0499	400	$\frac{1}{2}$	19·	·0498	·0001—
36.	·0500	·0499	400	$\frac{1}{2}$	15·1	·0497	·0002—
37.	·0500	·0499	400	$\frac{1}{2}$	19·	·0498	·0001—
38.	·1001	·0999	400	1	23·1	·0993	·0006—
39.	·1001	·0999	400	1	17·93	·0997	·0002—
40.	·1001	·0999	400	1	22·92	·0997	·0002—
41.	·1001	·0999	400	1	18·	·0997	·0002—
42.	·1001	·0999	400	1	16·	·0996	·0003—
43.	·1498	·1495	600	$1\frac{1}{2}$	23·26	·1493	·0002—
44.	·1498	·1495	600	$1\frac{1}{2}$	16·66	·1493	·0002—
45.	·1498	·1495	600	$1\frac{1}{2}$	26·87	·1475	·0020—
46.	·1996	·1992	800	2	22·38	·1990	·0002—
47.	·1996	·1992	800	2	17·29	·1999	·0007+
48.	·1996	·1992	800	2	22·20	·1991	·0001—
49.	·4045	·4037	1600	4	16·03	·4042	·0005+
50.	·4045	·4037	1600	4	16·2	·4023	·0014—
51.	·4018	·4010	1600	4	16·34	·4007	·0003—
52.	·5051	·5041	1800	4	15·27	·5026	·0015—

As seen in the table this process is very accurate, especially in the use of small amounts of ferric oxide. The introduction of cupric sulphate as recommended by Oudemans, or of sodium salicylate according to Haswell's method, seems to be unnecessary and only complicates the process.

In treating ferric oxide, the following method of procedure is recommended. Dissolve an amount not exceeding 0·2 gm. of the oxide in hydrochloric acid, evaporate to a pasty mass, dilute to about 800^{cm³} with freshly boiled water, add a drop of potassium sulphocyanide, and into this solution run 50^{cm³} of approximately $\frac{n}{10}$ sodium thiosulphate; allow the liquid to stand until perfectly colorless and determine the excess of thio-sulphate by $\frac{n}{10}$ iodine and starch. For quantities of iron oxide up to 0·2 of a gm. this process is quick and most accurate; when care is taken to preserve the relations of acidity and dilution, twice the amount of ferric oxide mentioned above may be handled.

In conclusion I wish to thank Prof. F. A. Gooch for his kind advice and many suggestions.

ART. V.—*The Mouth of Grand River*; by E. H. MUDGE.

REFERENCE to a map of Michigan will show that the mouth of Grand River, as commonly understood, is at Grand Haven, where the chief river of the State loses itself in the waters of Lake Michigan. But there is another point seventy miles inland which to one familiar with the old river valley, with its varied and interesting history during recent geological times, presents itself to the mind as the mouth of Grand River in a very interesting sense.

The history of this old river valley, in the days when it served as an outlet for the glacial lake Saginaw, has become quite well known to the geological world through the labors of several enthusiastic investigators, notably Mr. Frank B. Taylor, whose final solution of the chief problem here presented was first made public through a paper* read before the Geological Society of America in 1896. To understand thoroughly the matters under discussion in the present paper, a reading of Mr. Taylor's able paper is recommended, especially pages 48 to 54. The point of chief importance to the present discussion is that at one time a great glacial stream, three-fourths of a mile in width as indicated by the old valley, flowed across the peninsula from Lake Saginaw to Lake Chicago. At the point above referred to, in the eastern part of Ionia County (see map accompanying Mr. Taylor's paper), this great river received the waters of another stream, which had its rise far to the south, almost within shouting distance of the Indiana line. This stream was the upper part of what is now known as Grand River. There is no reason to believe that it was ever any larger than at present, and it was therefore but a branch of the great glacial river, with its mouth at the point above indicated.

Long ago the sources of the glacial river failed, and the wide valley with its record-bearing deposits was laid bare to await the time when the inquisitive geologist should investigate its secrets. Among other things thus rendered accessible are the fine river-mouth deposits about this old mouth of Grand River.

The Pewamo outlet (as the glacial river has been named by Mr. Taylor) was relatively a sluggish stream, its fall being something less than one foot per mile, while the fall of the upper Grand is three or four times as great. The surface of

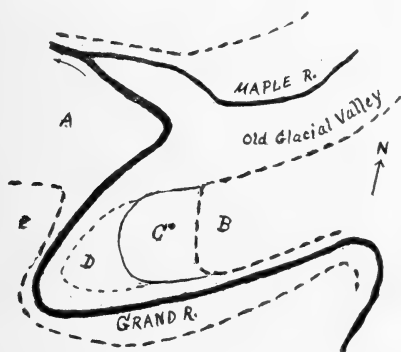
* "Correlation of Erie-Huron Beaches with Outlets and Moraines in South-eastern Michigan," by Frank Bursley Taylor, Bulletin of G. S. A., vol. viii, January, 1897.

the country through which the latter flows is composed chiefly of loose drift materials, well calculated to supply to the stream large quantities of sediment, which, in obedience to a well known law of river action, would be precipitated at the point where the stream joined its waters with a body of still water or with a slower stream. In this case such deposition took place at the old mouth, and in consequence the wide valley here exhibits some interesting features.

The first of these to attract the attention of the observer is the curious meanderings of the two streams before a junction is effected. The Maple River, which occupies the old valley above this place, flows in a channel near the center of the same until a point opposite the old mouth is reached, when it veers over against the north wall of the valley (see map). The Grand, coming in from the south, makes its way through the mass of old sediments (actually flowing "up stream" with reference to the glacial valley, in order to do so), until within a few rods of the Maple, and then turns down the valley and flows nearly parallel with the Maple for some distance before forming a junction, beyond which the united streams keep close to the north side of the valley for four or five miles. It is readily seen that these peculiar conditions are due to the clogging of the valley, in the vicinity indicated by A on the map, by the abundant sediment brought down by the Grand. There is a marked contrast between this area of abundant sediment and that a little farther to the east on the opposite side of the Grand. The latter is subject to overflow during freshet periods, while the former is built up to a considerable height above high water. These conditions continue for about two miles down the valley, along the south side, the filling being so extensive that the steep bluffs are partly obliterated, being replaced by a more gentle declivity. A well-defined terrace, which will be again referred to farther on, also tends to destroy the bluff feature. Immediately above the mouth the bluffs are again steep and prominent.

Some terraces about the old mouth are of considerable significance. When Mr. Taylor examined the valley of the Pewamo outlet in 1896, he called on the writer at Ionia and together we searched in that vicinity for terrace remnants that might indicate the height of the water in the glacial stream, but found nothing of a definite character. I suggested to him that such terraces may have been sheltered and preserved about this old river mouth, but rain and lack of time prevented a visit. I have since had opportunity to study the locality, and am able to report several well-defined and quite extensive terraces.

In the days of the glacial outlet there appears to have been here a small embayment, half a mile or more in extent in either direction. This embayment and the terraces now existing within it are indicated on the accompanying map. The heavy broken line indicates the bluff margin of the main valley and the embayment. From the high ground at B one descends abruptly to the terrace C. This is perhaps the most important of the series. Its elevation has not been measured, but it may be said roughly to occupy a place about midway between the top and the bottom of the main valley. Its surface is smooth and even, with abundant coarse sand and gravel upon it—a sort of gravel loam—together with patches of vegetable mould. South of this terrace, on the opposite side of the Grand,



there is a corresponding terrace, sharply defined but only a few rods in width—a mere shelf against the face of the steep bluff. Terrace C inclines gently to the west, the total descent being perhaps 15 or 20 feet. This terrace is so definite a feature of the locality that one can scarcely resist the conclusion that it marks a stage of the ancient river. An eye estimate of its elevation, made from the railway station across the valley at Muir, places it about 20 or 30 feet above the station, which is 656 feet above sea-level. An elevation of from 675 to 685 feet may therefore be taken as a fair estimate.

The nearest point to which Mr. Taylor traced the old beaches of the Saginaw Valley is at Maple Rapids, 25 miles away. At that place he assigns to the Forest beach, the lower of the two, an approximate elevation of 680 feet. The correspondence between this figure and the estimated elevation of terrace C is so close that the conclusion that they are equivalents is quite irresistible.

The descent from C to D is well marked but not steep. The surface is flat and several feet above the annual overflow of the Grand. It apparently corresponds in height with the sediment-filled area at A, and its presence appears to have no special significance. The two terraces described form the site of the village of Lyons.

A third terrace, high above the others, is found across Grand River to the west, covering a considerable area at E. Its limit is marked by a line of low hills, beginning near the big bend of the Grand and extending across northwest to the main valley. It is this terrace that helps to modify the bluff feature in this vicinity, above referred to. It may quite likely be correlated with a high terrace remnant seen at Ionia and with others mentioned by Mr. Taylor, but it is, I think, much better defined and more extensive than any of its probable equivalents hitherto observed. Its position is such that it may be considered tentatively as a portion of the Duplain beach, which Mr. Taylor traced as far as Maple Rapids.

The evidence from this little embayment is on the whole quite in harmony with that from other sources, in its bearing upon the history of the Pewamo outlet.

Lyons, Mich.

ART. VI. — *Electrical Measurements*; by HENRY A. ROWLAND and THOMAS DOBBIN PENNIMAN.*

IN a previous article† mention was made of some work then being carried on at the Johns Hopkins University to test the methods for the measurement and comparison of self-inductance, mutual inductance, and capacity there described.

In the present paper, there will be given an account of the experiments performed with some of the methods described in the previous article, together with a method for the direct measurement of the effect of electric absorption in terms of resistance.

The methods that were tried were 25, 26, 9, 3, 12 and 6.

APPARATUS.

Description of the electro-dynamometer, dynamos, coils, condensers, resistances and connections used in the experiments.

Electro-dynamometer. — The electro-dynamometer was one constructed at the University, having a sensitiveness, with the coils in series, of 1 scale division deflection for .0007 ampere.

The hanging coil was made up of 240 turns of No. 34 copper wire B and S gauge. The coil was suspended by a bronze wire connected with one terminal of the coil. The other terminal of the coil was a loop of wire hanging from the bottom of the coil and attached to the side of the case; both the suspension and the loop were brought out to binding posts. The resistance of the coil with suspension was 21.7 ohms.

The fixed coils were made up of 300 turns each of No. 30 B and S gauge copper wire. The coils were wound on cup-shaped metal forms and soaked in a preparation of wax. The form was then removed and the coils placed a radius apart as in the arrangement of Helmholtz.

Dynamos. — There were two dynamos used, a Westinghouse alternator, and a small alternating dynamo constructed at the University. The Westinghouse dynamo was one having 10 poles so that each revolution of the armature produced 5 complete periods. The period of this dynamo was determined by taking the time of 1000 revolutions of the armature. This was accomplished by having the armature make an electric connection with a bell every 200 revolutions and taking the

* This Journal, iv, p. 429, December, 1897; Philosophical Magazine, January, 1898.

† Abstract of Thesis for the degree of Ph.D.

time of 5 of these. The taking of the speed during every experiment gave more regular results, as the speed was constantly changing, the dynamo being run by the engine in the University power-house when it was subject to great change of load. This dynamo had a period of about 132 complete periods per second.

For the production of a current of less period than that of the Westinghouse, the small alternator constructed at the University was used. This dynamo was run by a small continuous Sprague motor. The armature of the small alternator consisted of 8 coils, which coils were fastened flat on a german silver plate, the plate revolving between 8 field pieces producing 4 poles. The object of having the coils of the armature on a metal plate was to secure a nearly constant speed. The metal plate produced a load that varied as the velocity and due to induced currents in the plate. The varying load, depending on the velocity of the moving plate, produced a nearly constant speed, which rendered unnecessary the constant taking of the speed. When this dynamo was used, the speed was only determined two or three times during a series of readings or experiments. The average of these determinations was taken as the speed during the whole series of experiments under consideration.

Coils.—The coils whose inductances were determined were all made in the same way, being wound on a metal form and soaked in a preparation of wax. When the wax was hard the metal form was removed. This enabled the coils to be placed close together, as their sides were flat and smooth. The coils all had the same internal and external diameter, but their width varied, that being determined by the number of turns that were desired.

Coils. P_1 . External diameter 35.46^{cm}, internal diameter 23.8^{cm}, was made up of about 1200 turns of No. 16 B and S gauge single covered cotton copper wire, roughly wound; the turns were not smooth; self-inductance as finally determined .566 henry.

P_2 . Same dimensions. Turns were put on evenly. The number of turns was 1300 of No. 16 B and S single covered cotton copper wire. Self-inductance .724 henry.

A. Same internal and external diameters as P_1 , but the width was 4.3^{cm}. Number of turns 3700 No. 20 B and S gauge single covered cotton copper wire. Self-inductance as determined 5.30 henrys.

B_1B_2 . This coil was made by winding two wires in parallel and all four of the terminals brought out to binding posts. Thus the coils could be used as two single coils, when the coils will be denoted by the symbols B_1 and B_2 as the case may be,

or as a single coil, the coils B_1 and B_2 being joined up in series or in parallel. The dimensions of the coils B_1 , B_2 were the same as A. Each of the coils B_1 and B_2 were made up of 1600 turns of No. 22 B and S single covered cotton copper wire. The self-inductance of these coils taken separately when compared with P, which was determined absolutely, was nearly 1 henry. On this account B was taken as being 1 henry, and the other coils were compared with it as a standard.

C. Same dimensions as P_2 . Number of turns 1747 of No. 22 B and S single covered cotton copper wire. Self-inductance as determined 1.30 henrys.

Condensers.—2 and 3. Two paraffined paper condensers that had a capacity of 2 and 3 microfarads respectively.

$\frac{1}{3}$ d Troy. A $\frac{1}{3}$ d microfarad standard mica condenser built by the Troy Electric Co.

$\frac{1}{3}$ d Elliott. A $\frac{1}{3}$ d microfarad standard mica condenser built by Elliott Bros.

Resistances.—The resistances used in the experiments were of two kinds, those wound with double wire so as to have no self-inductance, as the ordinary resistance box, and those wound on frames or cards which had some small self-inductance, but almost no electrostatic capacity. The resistances which had self-inductance are called open resistances to distinguish them from resistance boxes, and were of different kinds and dimensions.

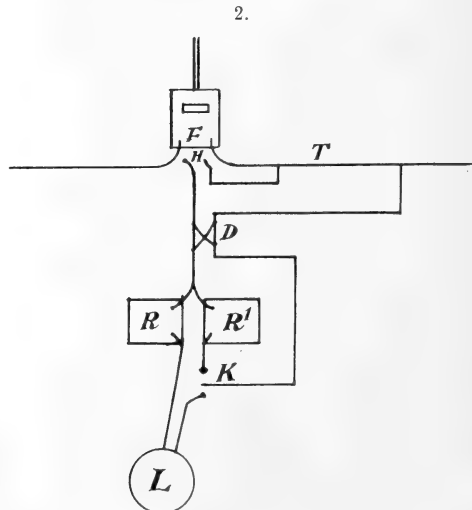
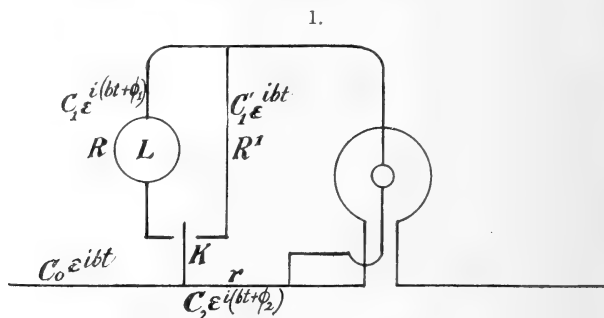
Sources of Error and Experimental Difficulties.

In all work with alternating currents there are two great sources of error that have to be guarded against. These are the errors that may arise from the inductance of one part of the apparatus on another, as, for example, the direct induction of a coil in the circuit on the coils of the electro-dynamometer, and the effect of the electrostatic capacity of the leads and connections. In connecting the coils great care had to be taken to avoid the effect of electrostatic action of the leads and connections. For if there was a current of very considerable magnitude, the difference of potential between the terminals of the coil might be great. If the connections under these circumstances were made with double wire, as is customary, a great error was introduced due to the electrostatic capacity of the leads. The error was sometimes as much as 7 per cent (see method 24). This error could be shown to be due to the electrostatic action of the leads by shifting a resistance in circuit with the coil in question from one end of the double wire to the other. The effect of this was to still further increase the difference of potential between the leads, and this increased the error. Experiments of this character showed the necessity

of using open leads and open resistances having little or no capacity in all cases in which the coils experimented on and the resistance boxes used in their determination have a current of any considerable magnitude passing through them. In several of the following methods constancy of current was necessary. This was accomplished by various means that will be described in their actual application.

METHODS.

The methods that were tried were 25, 26, 9, 3, 12 and 6 described in this Journal, December, 1897.*



Method 25.—Method of equal deflections. Absolute method for the determination of self-inductance or capacity in terms of electromagnetic units.

* Phil. Mag., January, 1893.

In this method the hanging coil is shunted off the fixed coils circuit, and this with a non-inductive resistance in circuit with the hanging coils is made the same as that of a certain inductive resistance in circuit with the hanging coil. The connections are made as in the figs. 1, 2, where $C_0\epsilon^{ibt}$, $C_1\epsilon^{i(bt+\phi_1)}$, $C_2\epsilon^{i(bt+\phi_2)}$ are currents. R , R' , r , resistances. They represent the entire resistance of their respective branches. L represents self-inductance of the coil by which it is placed. The outer circle in fig. 1 represents the fixed coils and the small circle the hanging coil of the electro-dynamometer. In fig. 2 the terminals of the fixed and hanging coils are represented by F and H. D is a reversing commutator. K is a key to send the current first through the inductive and then through the non-inductive resistance. $b = 2\pi n$, n = complete alternation per sec. This is the general notation adopted throughout the article.

The quantity to be found is $C_0C_1 \cos \phi_1$, which is proportional to the deflection of the hanging coil in the two positions of K.

In one position

$$C_1\epsilon^{i(bt+\phi_1)}(R+ibL) = C_2\epsilon^{i(bt+\phi_2)}r = (C_0\epsilon^{ibt} - C_1\epsilon^{i(bt+\phi_1)})r$$

Therefore

$$C_0C_1 \cos \phi_1 = C_0 \frac{2r(R+r)}{(R+r)^2 + b^2L^2} a D$$

In the other position of K

$$C_1'\epsilon^{ibt}R' = C_2'\epsilon^{i\phi_2}r = (C_0\epsilon^{ibt} - (C_1'\epsilon^{ibt})r$$

Therefore

$$C_0C_1' = C_0 \frac{r}{R'+r} a D'$$

$\phi = 0$, as ϕ is an angle whose tangent is $\frac{bL}{R'}$ and $C = 0$ nearly.

In the case of equal deflection $D = D'$ and therefore

$$b^2L^2 = (R' - R)(R + r)$$

If capacity had been used in the place of self-inductance the formula would be

$$\frac{1}{b^2c^2} = (R' - R)(R + r)$$

If self-inductance and capacity were used in series

$$b^2\left(L - \frac{1}{b^2c}\right)^2 = (R' - R)(R + r)$$

The application of this formula to the measurement of self-inductance gave results that agreed to within the accuracy with which the period of the alternations could be determined.

That is, the results agreed to within about 1 per cent. In the determination of L the resistance in circuit R was varied from the least possible resistance as determined by the coils up to 1000 ohms and more, and the self-inductance was determined under these various conditions. These results agreed among themselves, and were apparently independent of the resistance in circuit with it. In the application of this method to the determination of capacity, however, great trouble was encountered, as the capacity apparently varied both with the resistance in circuit with it and with the period. This variation was regular for each period, the value derived depending on the resistance in circuit. This irregularity of derived value of the capacity led to the investigation and development of Maxwell's formula on the effect of absorption, a necessary characteristic of heterogeneous substances.

When the formula was deduced, as may be seen in the article already referred to, the absorption comes in as an added resistance, the resistance being constant for a given period. By an inspection of the results this was found to be the case. The finding of the resistance due to absorption in this method is one of approximation, but the values deduced compare very favorably with those determined by direct measurement, as will be seen later when various results are collected. In the actual experiments the condensers used were two paraffined paper condensers of about 2 and 3 microfarads. The currents used had different periods, as seen in the table following, where $n = 133, 53.3, 31.9$ and 14 .

The process was to place in the condenser circuit a resistance R , and then to move the key K back and forth until R' was found that gave the same deflection. D , fig. 2, was now reversed and the process repeated. This was repeated with different values of R and n and the apparent capacity. This gave great variation of apparent capacity with different values of R , which should not be the case, and, therefore, gave a means of finding the resistance due to absorption or absorption resistance, as we will designate, by approximation. As the effect of absorption is a resistance it is possible to find what resistance, if added to R , will make all the values of the capacity as determined for the different values of R the same. Therefore it should be the same for any two values of R . Calling the two values of R in the two cases R_1 and R_2 respectively and the two corresponding values of R' , R'_1 , and R'_2 , and let A be the added resistance due to absorption, the capacity should be the same in the two cases, or

$$\frac{1}{C^2} = [R'_1 - (R_1 + A)] [R_1 + A + r] = [R'_2 - (R_2 + A)] [-R_2 + A + r]$$

$$\therefore A = \frac{(R'_2 - R_2)(R_2 + r) - (R'_1 - R_1)(R_1 + r)}{R'_1 - R'_2 - 2(R_1 + R_2)}$$

From this A is found for the period used. By doing this for a number of different values of R , the true value of A is approximated. A was thus found for the condensers 2 and 3 microfarads with different values of n . The calculations were again performed adding to the different values of R a constant resistance A . The capacity that was found when A is added to R is called the corrected capacity. In the table below are collected the corrected values of the capacities together with n and the resistance A .

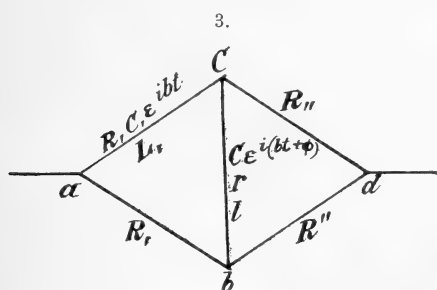
Capacity	4.94	4.96	4.96	4.64	microfarads.
n	131.1	53.3	31.98	14.	complete alternations.
A	5.19	20.5	34.09	139.62	absorption resistance in ohms

The last value of the capacity seems to be an error, possibly one of calculation. However, the results seem to show a nearly constant capacity, but a resistance increasing rapidly with decrease of period, as Maxwell's formula shows. The constant value of the capacity remains to be explained.

But in the above, determinations of absorption resistance are by approximation. Professor Rowland has, therefore, devised a method by which it can be measured directly. This method, with the results that have been derived by it, will now be given.

Method for the Direct Measurement of Absorption Resistance.

In a Wheatstone bridge (fig. 3) let the resistance of the different arms be denoted by R , R' , R'' , R''' and r . Let R have in circuit a self-inductance L , and let r have in circuit with it a self-inductance.



Let $C_i e^{ibt}$ be the current through R , and $C e^{i(bt+\phi)}$ be the current through r when a periodic electromotive force is applied to a and d in the figure.

Let C_i' be the current through R , and C' be the current through r when there is a constant difference of potential between a and d . The ratio of the current in this case is

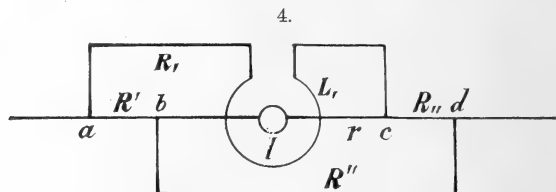
$$\frac{c'}{C_i'} = \frac{R''R_i - R'R_{ii}}{R'(R'' + R_{ii}) + r(R' + R'')}$$

When a periodic electromotive force is applied to a and d , the ratio of the currents in this case is

$$\frac{c}{C_i} e^{i\phi} = \frac{R''R_i - R'R_{ii} + ibR''L_i}{R'(R'' + R_{ii}) + r(R' + R'') + ibl(R' + R'')}$$

Separating the real and imaginary parts

$$\frac{c}{C_i} \cos \phi = \frac{(R''R_i - R'R'')[R'(R'' + R_{ii}) + r(R' + R_{ii})] + b^2lL_iR''(R' + R'')}{[R'(R'' + R_{ii}) + r(R' + R'')]^2 + b^2l^2(R' + R'')^2}$$



If now the fixed coils of the electro-dynamometer are placed in the R_i arm of the bridge, and the hanging coil is placed in cross connection of the bridge, as in fig. 4, the different resistances may be adjusted until there is no deflection, in which case $\phi = 90^\circ$ or $\cos \phi = 0$, therefore

$$(R''R_i - R'R_{ii}) [R'(R'' + R_{ii}) + r(R' + R'')] + b^2lL_iR''(R' + R'') = 0$$

$$\therefore R''R_i = R'R_{ii} - b^2lL_i \frac{R''(R' + R'')}{R'(R'' + R_{ii}) + r(R' + R'')}$$

If in connection with L_i a capacity C is added, the formula becomes, substituting for L_i , $L_i - \frac{1}{b^2c}$

$$R''R_i = R'R_{ii} - \left(b^2lL_i - \frac{l}{c} \right) \frac{R''(R' + R'')}{R'(R'' + R_{ii}) + r(R' + R'')}$$

In most cases since l and L_i are generally the self-inductances of the instruments the term b^2lL_i can be neglected in comparison with $\frac{l}{c}$ and the equation becomes

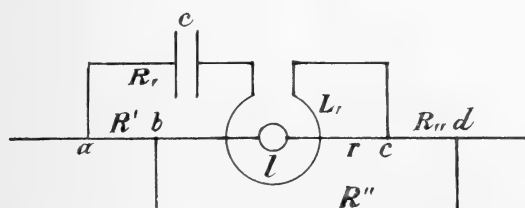
$$R''R_i = R'R_{ii} + \frac{l}{c} \frac{R''(R' + R'')}{R'(R'' + R_{ii}) + r(R' + R'')}$$

In this equation R_i includes both the ohmic and the absorption resistance. The value of R_i is determined in terms of known quantities, that is the resistance and l and C . It was not

necessary that l and C should be exactly known as the last term in the equation above plays the part of a correction term, and is in all cases below small and in some cases negligible. The capacities that were used in the experiments were the 2 and 3 microfarads, the $\frac{1}{3}$ microfarad Elliott condenser, and the $\frac{1}{3}$ microfarad Troy condenser.

Experiments—The process of experimenting was to apply a periodic electromotive force to a and d , and to adjust the different resistances until there was no deflection of the coil in

5



the same way as in the ordinary measurement of resistance on a Wheatstone bridge. The different resistances R' , R'' , R_r , and r being known, the apparent value of the resistance R_l was found, and knowing the ohmic resistance of the R_l circuit, the absorption resistance appears as the difference.

Some interest lies not alone in that the method is applicable, but that it confirmed the supposition that absorption resistance acts as an ordinary ohmic resistance in series in the circuit. This was confirmed by the fact that when condensers were in series and in parallel, their absorption resistances acted under these conditions like ohmic resistances, being increased in the one case and decreased in the other, and in the right ratio. This agreement was not exact, as the absorption resistance was extremely sensitive both to change of period and change of temperature. The great sensitiveness to change of temperature was shown either by letting the current go through the condensers for a little time, or placing the condensers before a hot air flue; in either case after cooling, the absorption resistance returned to its original value. The cooling was very slow, as there was very little radiation from the condensers inclosed in wooden boxes.

The results are now given for the condensers 2 and 3 microfarads. In the calculation of the results the last term of the equation, that is $\frac{l R''(R' + R'')}{e R'(R'' + R_r) + r(R' + R'')}$ has been left out, as it was very small when condensers 2 and 3 microfarads were used.

CONDENSERS 2 AND 3 MICROFARADS IN PARALLEL.

 $n=134$, $l=.0007$, \therefore last term negligible.

R''	R_{μ}	r	R'	R_{ν}	Resis. of R' circuit in ohms.	Resistance due to absorption.
422.6	488.6	5457.3	347.9	39.29	33.77	5.30
1488.6	488.2	"	123.4	40.50	"	6.73
984.1	"	"	82.1	40.72	33.81	6.91
2671.6	"	"	22.5	41.116	"	7.30
423.0	"	"	357.3	41.237	"	7.42
5474.3	"	"	464.5	41.42	"	7.61
6734.	"	"	374.9	41.67	"	7.86
1 ohm in $R'' = \frac{2}{3}$ scale division.						
7486.	"	"	638.6	41.64	"	7.83
9466.	"	"	81.15	41.85	"	8.04

Condensers 2 and 3 placed before the register and heated for 1 hour :

7489.7	488.27	"	713.8	46.534	34.33	12.20
--------	--------	---	-------	--------	-------	-------

After standing $1\frac{1}{2}$ hours in air at temperature of $12^{\circ}2$ C. condenser has been open so that resistances have been cooled :

1240.5	487.8	"	109.	42.86	34.	8.86
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After standing some little time :

7482.5	487.8	"	651.6	42.47	34.	8.49
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The above table shows conclusively the heating of the condenser by the current, and the dependence of the absorption upon the temperature.

CONDENSERS 2 AND 3 IN PARALLEL. $N=57.6$.

R''	R_{μ}	R'	r	R_{ν}	R_{ν} in ohms.	A.
348.5	488.6	396.3	11020.7	55.61	33.77	21.84
7488.	"	849.2	"	55.41	"	21.64
"	"	844.1	4026.	55.07	"	21.30
3485.	"	396.1	"	55.53	"	21.81

Average, 21.63

$N=56.6$ per second.						
3485.	200.24	976.7	4026.	56.00		22.23

Comparing these values with those found in the use of method 25 the agreement is at once apparent.

$N=$	134.	131.	57.6	56.6	53.
Method 25		5.19			20.5
Direct measurement.	5.30 cold 7.00 warm		21.63	22.23	

It should be remembered, in comparing the results, that the values obtained by Method 25 would naturally be smaller than those found by direct measurement, as in Method 25 the current going through the condensers was extremely small; there was therefore practically *no* heating.

The experiments that confirm the mathematical theory that the absorption resistance could be treated as ordinary ohmic resistance were performed with the two condensers, $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott microfarad condensers. These are next given.

In these results it was necessary to take into account, in the calculation of the apparent value of R_p , the last term of the equation, that is

$$\frac{l}{c} \frac{R''(R' + R'')}{R'(R'' + R_p) + r(R' + R'')}$$

$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series, 1 o'clock.

R''	R_p	R'	r	Apparent value of R_p	Ohmic resist- ance of R_p	Absorption resistance A.
4751.8	499.9	404.8	4754.	43.141	34.143	8.998

$\frac{1}{3}$ Troy, 2 o'clock.

4750.	497.75	352.4	"	37.288	34.144	3.144
-------	--------	-------	---	--------	--------	-------

$\frac{1}{3}$ Elliott, 2.45 o'clock.

4749.3	497.67	390.3	"	41.260	"	7.116
--------	--------	-------	---	--------	---	-------

$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in parallel, 4 o'clock.

4749.3	497.6	350.23	"	36.94	34.15	2.79
--------	-------	--------	---	-------	-------	------

$\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series.

4748.5	497.55	418.15	"	44.612	34.12	10.492
--------	--------	--------	---	--------	-------	--------

Calculating what the absorption resistance should be for $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in series, from the absorption resistances of the two condensers when determined separately, it is equal to 10.26 ohms, which is greater than the first and less than the last value above, showing that the condensers were heating during the experiments. Calculating the absorption resistance of $\frac{1}{3}$ Troy and $\frac{1}{3}$ Elliott in parallel in the same way, it is equal to 2.209 ohms, which is less than the value afterwards obtained by experiment for the same reason.

The method was shown not to be based on any false supposition, by substituting in place of the condenser a coil of known self-inductance. When this was done the value of R_p as calculated from the other resistances and the self-inductances should be the same as the actual ohmic resistance of the circuit.

This was tried with two coils P_2 and A and the agreement was remarkably close, as seen in the next table.

Coil P used in place of condenser in the R_p circuit:

R''	R_p	R'	r	Deducted value of R_p	Actual value of R_p
474.9	487.8	758.2	5457.	77.86	77.8

Coil A in place of condenser in the R_p circuit:

474.9	487.8	218.3	"	224.12	223.9
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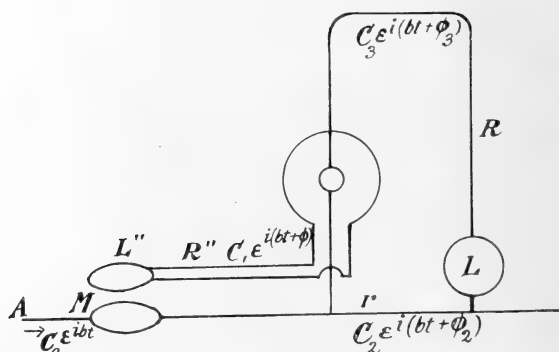
In these experiments great care was taken that the measurements of the resistances were performed immediately after the adjustment. In this way the actual resistances at the time of the experiment were obtained, and so the effect of the heating by the current was somewhat eliminated.

Methods 26, 9 and 3 give good results, but the methods that gave the most satisfaction were Methods 12 and 6, Method 12 being for the comparison of two self-inductances and Method 6 for the comparison of a self-inductance with a capacity. These give some remarkable results, the theory and deductions of the methods being as follows:

Method 12—Zero method for the comparison of two self-inductances.

Let the connections be made as in the figure where the hanging coil and the fixed coils are in two distinct circuits.

6.



Let $C_0 \epsilon^{ibt}$ etc. be the currents, A' and A'' reversing commutators, R'' , R and r the resistance of the different circuits, L'' and L the self-inductances, M the mutual inductance of the coils B_1 and B_2 by which it is placed. When a periodic electromotive force $a \epsilon^{ibt}$ is applied to A , B the quantity to be found is $C_1 C_3 \cos(\varphi_3 - \varphi_1)$ where $\varphi_3 - \varphi_1$ is the difference of phase.

The current in the R'' circuit is then

$$C_1 \epsilon^{i(bt+\phi)} = \frac{ibMC_0 \epsilon^{ibt}}{R'' + ibL''} \quad (1)$$

The current in the R circuit is

$$C_3 \epsilon^{i(bt+\phi_3)} (R + ibL) = C_2 \epsilon^{i(bt+\phi_2)} r$$

$$\therefore C_3 \epsilon^{i(bt+\phi_3)} \frac{R + r + ibL}{r} = C_0 \epsilon^{ibt}$$

Substituting the value of $C_s \epsilon^{ibt}$ in equation (1) and simplifying, it becomes

$$C_i \epsilon^{i(bt+\phi)} = C_s \epsilon^{i(bt+\phi_s)} \frac{-b^2 LM + ibM(R+r)}{R''r - ibL''r}$$

Therefore the deflection is proportional to

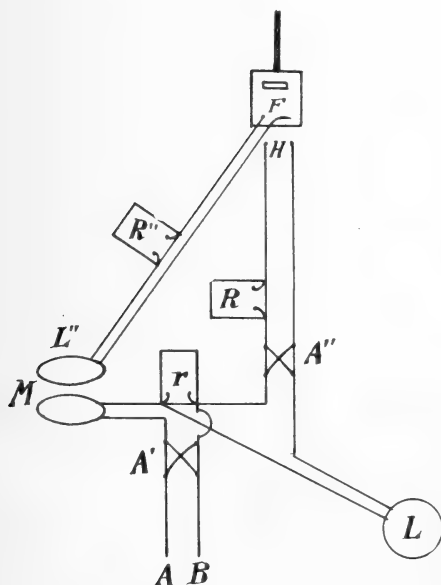
$$D \propto C_i C_s \cos(\phi_s \phi_i) = C_s^2 \frac{-b^2 LMR''r + b^2 L''M r(R+r)}{R''^2 r^2 + b^2 L''^2 r^2}$$

where D is the deflection. Therefore the condition for zero deflection is

$$-b^2 LMR''r - b^2 L''M r(R+r) = 0$$

$$\therefore \frac{L}{L''} = \frac{R+r}{R''}$$

7.



The condition therefore of zero deflection is independent of M. But M is one of the factors of the electromotive force in the R'' circuit, and on it therefore depends the sensitiveness, as it determines the current through the R'' circuit. In the first figures of this method the fixed coils are in the R'' circuit, and the hanging coil in the R circuit, but this is not necessary, as the fixed and hanging coils can be reversed. The choice of which of the above arrangements should be used depends on

the impedances of the two circuits, as other things being equal the smaller current should go through the hanging coil.

Experiments—The coils used in the experiments were coils P_1 , P_2 , C , B_1 , B_2 , and A , which coils are described on page 36. From the dimensions of P_2 and its self-inductance as found by Method 25, B_1 was designed to have a self-inductance of one henry. This will be shown to be nearly the case. For ease of comparison B_1 has been taken in the calculations of the results as being equal to one henry, and the other coils were compared with this coil as a standard.

In these experiments the connections were made as in the figure 47, the coil B_1 that was taken as the standard being placed in circuit with the fixed coils of the electrodynamicometer as L'' and the resistance of this circuit was unaltered during the experiments in any particular series. The coils whose self-inductances were to be determined were placed in the hanging coil circuit and the resistance R was changed until there was no deflection. The resistance of the two circuits, R'' and $R+r$ were then measured by a Wheatstone bridge.

The resistance r was in all cases small in order that $C_0 \epsilon^{ibt}$ should be large, and therefore by induction $C_0 \epsilon^{i(bt+\phi)}$ the current through the fixed coils was made large and the instrument sensitive. The method being very accurate, as will be seen later, great care had to be used to eliminate all sources of error, as for example, electrostatic action. In the first trial of the method small differences were noticed in the ratio of two self-inductances, depending both on the resistances used, and also on the connections of the coils, whether the leads were double, single, long or short. The same variation was noticed when several coils were joined in series and compared with another coil, and when these coils were compared separately and their sum taken.

This irregularity led to an investigation of the effects of various resistances and connections in one of the circuits, the other circuit being unaltered. A little farther on, the variation in the deduced value of the self-inductance of one of the coils, when different resistances and leads were used, will be given, which variation was caused by the electrostatic action of the connections, etc. (Page 37.)

The necessity of eliminating electrostatic action made obligatory the use of open resistances which had small self-inductances. These resistances were of three kinds—resistances in the form of spirals, resistances wound on thin strips of mica-rite or paper, and those wound on open frames; see page 37.

The self inductance of the first and second classes of resistances was very small, as in one case there were only a few turns, and in the other the cross-section was very small.

The third class were those wound on frames whose self-inductances were calculated. There were several resistances of 2000 ohms each, whose self-inductances were .0000436 henry, which would hardly affect the phase of the current or the impedance of the circuit.

These coils were subdivided into resistances of various amounts. Another frame resistance used was of 7463 ohms divided into parts of about 250 ohms each. The self-inductance of the entire 7463 ohms was .000105 henry.

As the open resistances were not divided into small amounts it was necessary to use resistance boxes for adjustment; as few ohms as possible were used in each case.

From the fact that the coils of the electro-dynamometer had self-inductance a correction was introduced in order that the ratio of the resistances should give the ratio of the self-inductances of the coils direct.

The value of this correction in ohms was calculated as follows:

Calculation of connection due to fixed and hanging coils.

Self-inductance of fixed coils $= f = .0164$ henry

" " " hanging coil $= h = .0007$ "

Correction due to fixed coils. From an inspection of the tables it is seen that

$$\frac{L}{B_1 + f} = \frac{R + r}{R''}, \text{ or } \frac{L}{1.0164} = \frac{R + r}{902}$$

where L is the self-inductance of some coil and $R + r$ is the corresponding resistance. B_1 is taken as equal to 1 henry

$$\therefore \frac{L}{R + r} = \frac{1.0164}{902}$$

But the comparison of L with $B_1 = 1$ is wanted, therefore both numerator and denominator of $\frac{1.0164}{902}$ are divided by 1.0164 or

$$\therefore \frac{L}{R + r} = \frac{1 = B_1}{887.45}$$

$$\therefore \frac{L}{B} = \frac{R + r}{887.45}$$

That is, the self-inductance .0164 henry of the fixed coils produced a correction of $887.45 - 902 = -14.55$ ohms, which must be applied to the R'' circuit if the self-inductance of that circuit is to be considered as 1 henry.

Correction due to hanging coil. The self-inductance = $\cdot 0164$ henry of the fixed coils gives a correction of $-14\cdot 55$ ohms, therefore the self-inductance $\cdot 0007$ henry of the hanging coil gives a correction of $-\cdot 62$ ohms to the $R+r$ circuit. Applying these corrections, the results obtained for the several coils under various conditions are given below. The results are given in the following order.

First. The values are calculated using double leads in the circuits but open resistances as far as possible.

Second. The variation of the apparent value of the self-inductance of one of the coils with different positions of the coil, resistances, and different kinds of leads.

Third. Short leads separated about 6 inches and crossed, used with all the coils except B_1 .

Fourth. Open leads and open resistances in the determinations. In the table R'' was open resistance plus the resistance of coil B_1 and fixed coils of instrument. $R+r$ was made up of the small coil and open resistance plus the amount in the Queen ordinary resistance box.

After all the inductive effect of the leads was removed and the ordinary resistance box used as little as possible, there was a different value obtained for the ratio of the self-inductances dependent on the position of the reversing commutator A' . With all the coils used the greater value occurred with the same position of A' . This was due to the electrostatic action between the coils B_1 and B_2 , for if the terminals of the coil B_2 and the commutator A' were reversed at the same time, there was no change in the value of the ratio of the inductances. This showed that it was dependent on the coil itself and not on the leads and it could therefore not be eliminated.

It is to be noticed that the values obtained for the lower number of alternations are always greater than those found with the higher number of alternations. This was caused by the electrostatic action of the turns of the coil on each other. In the case of the coil P_2 this effect would be caused by supposing a capacity of $\cdot 0007$ microfarads shunted across the terminals.

The results are now given comparing the different coils with B_1 as a standard and equal to 1 henry.

DOUBLE LEADS OF BELL WIRE AND OPEN RESISTANCES.

$r = 106$ ohms, $n = 45$ complete periods per second.

Coils.	R'' .	Correc.		Queen.	$R+r$.	Cor- rec.	Aver- age.	Com. A' .	Ratio.
$P_1 + P_2$									
+ C	901.6	-14.55	887.05	292	2300.2	-.62	2304.9	1	2.5983
"	"	"	"	310	2311.0	"	"	2	"
C	"	"	"	19	1158.3	"	1159.0	1	1.3099
"	"	"	"	22	1161.2	"	"	2	"
$C + P_1$	"	"	"	103	1659.	"	1661.2	1	1.8727
"	"	"	"	109	1664.8	"	"	2	"

Coils.	R".	Correc.		Queen.	R + r.	Cor- rec.	Aver- age.	Com. A'.	Ratio.
C + P ₂	901.6	-14.55	887.05	92	1800.2	-62	1802.6	1	2.0288
"	"	"	"	99	1806.5	"	"	2	"
A	901.7	"	887.15	149	4776.5	"	4786.5	1	5.3956
"	"	"	"	196	4818.0	"	"	2	"

Current increased about $2\frac{1}{2}$ times.

A	"	"	"	141	4787.0	"	4781.3	1	5.3898
"	"	"	"	184	4807.	"	"	2	"
A + C	901.6	"	887.05	211	5936.	"	5958.3	1	6.7170
"	"	"	"	264	5982.	"	"	2	"
A + C × P ₂	"	"	"	51	6575.5	"	6602.5	1	7.4430
"	"	"	"	104	6631.0	"	"	2	"
A	902.	"	887.45	158	4778.9	"	4795.25	1	5.4036
"	"	"	"	192	4813.	"	"	2	"
P ₁ + P ₂	"	"	"	183	1146.5	"	1146.7	1	1.9922
"	"	"	"	186	1148.5	"	"	2	"
P ₂	"	"	"	7	643.15	"	642.67	1	.7242
"	"	"	"	8	643.6	"	"	2	"
P ₁	"	"	"	91	502.5	"	502.16	1	.5658
"	"	"	"		503.1	"	"	2	"

DOUBLE LEADS. n = about 133 complete alternations per sec.

Coils.	R".	Correc.		Queen.	R + r.	Cor- rec.	Aver- age.	Com. A'.	Ratio.
P ₁	901.9	-14.55	887.35	90 + s	500.4	+62	499.69	1	.5631
"	"	"	"	"	500.23	"	"	2	"
P ₂	"	"	"	3	639.35	"	638.85	1	.7198
"	"	"	"	4	639.6	"	"	2	"
A	901.87	"	887.32	?	4742.2	"	4750.48	1	5.3537
"	"	"	"	133	4760.0	"	"	2	"
C	901.9	"	887.35	44	1151.4	"	1150.94	1	1.2970
"	"	"	"	44	1151.4	"	"	2	"

In the above determinations the coils were arranged in the way as indicated in the figure having leads of double bell wire.

A SERIES OF DETERMINATIONS OF A UNDER VARIOUS CONDITIONS.

Open resistance R on table (original position).

Coils.	R".	Correc.		Queen.	R + r.	Cor- rec.	Aver- age.	Com. A'.	Ratio.
A	902.0	-14.55	887.45	149 + s	4776.5	-62	4786.58	1	5.3936
"	"	"	"	196 + s	4818.	"	"	2	"
"	901.95	"	887.4	?	4783.5	"	4795.38	1	5.403
"	"	"	887.4	190 + s	4808.5	"	"	2	"

Open resistance R moved up to coil A (b_1).

"	"	"	"	?	?	"	"	"	"
"	"	"	"	?	4518.	"	4517.38	2	5.0905

Open resistance R moved to the other side of A (b_2).

"	"	"	"	144 + s	4518.	"	4518.88	1	5.0922
"	"	"	"	147 + s	4521.	"	"	2	"

Coil A placed in P₁ position and open resistance R restored to its position, and 159' of double wire added to the circuit.

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Coils.	R".	Correc.		Queen.	R + r.	Cor- rec.	Aver- age.	Com. A'.	Ratio.
A	901.95	-14.55	887.4	547 + 4129	547	-.62		1	
					4676		4693.38	2	5.2888
"	"	"	"	583 + 4129	583				
					4712				

Coil A at end of double wire $69' + 159' = 228'$ long.

"	"	"	"	607 + 4129	607				
"	"	"	"		4736				
				634 + 4129	634				
					4763				

New leads placed in B_1 circuit, the wires were about 6" from each other.

"	902.6	"	888.05	569 + 4129	569				
"	"	"	"		4698				
				594 + 4129	594		4709.88	1	5.3038
					4723			2	

Open resistance placed next Coil A.

"	"	"	"	663 + 4129	663		4791.3	1	5.3956
"	"	"	"		4292		4292.	2	
"	"	"	"				.7		
							0.6		

In the following all connections were made with open leads, and open resistances were used.

Pe- riod.	Coils.	R".	Correc.		Queen.	R + r.	Cor- rec.	Aver- age.	Com. A'.	Ra- tio.
40	P_1	902.	-14.55	887.45	90 + s	503.07	-.62	502.71	1	.5664
"	"	"	"	"	90 + s	503.6	"		2	
133	"	"	"	"	88 + s	522.53	"		1	
"	"	"	"	"	88 + s	502.15	"	501.72	2	.5653
40	P_2	902.55	"	888.	17 + s	644.3	"		1	
"	"	"	"	"	18 + s	644.76	"	643.91	2	.7251
133	"	"	"	"	17 + s	643.05	"		1	
"	"	"	"	"	17 + s	643.1	"	642.45	2	.7234
40	C	902.4	"	887.85	28 + s	1159.6	"		1	
"	"	"	"	"	28 + s	1159.1	"	1158.73	2	1.3050
133	"	"	"	"	24 + s	1157.0	"		1	
"	"	"	"	"	26 + s	1158.8	"	1157.28	2	1.3034
40	$C + P_1$	902.	"	887.45	105 + s	1658.8	"		1	
"	"	902.	"	"	110 + s	1664.1	"	1660.77	2	1.8713
133	"	"	"	"	101 + s	1656.7	"		1	
"	"	"	"	"	106 + s	1660.3	"	1657.96	2	1.8682
40	$C + P_2$	902.5	"	887.95	10 + s	1803.0	"		1	
"	"	"	"	"	12 + s	1805.0	"	1803.3	2	2.0261
133	"	"	"	"	8 + s	1800.5	"		1	
"	"	"	"	"	8 + s	1800.2	"	1799.65	2	2.0221

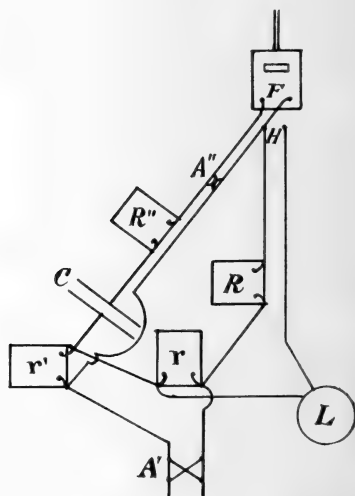
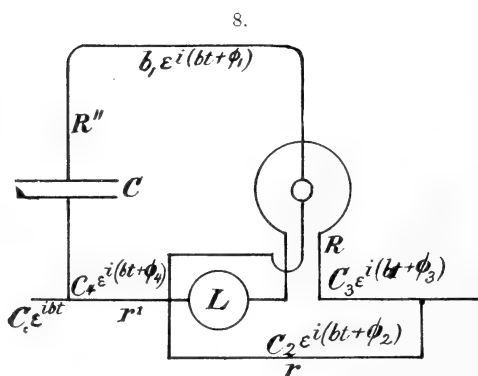
Period.	Coils.	R".	Correc.		Queen.	R+r.	Cor-rec.	Average.	Com.	A'.	Ratio.
40	P ₁ +P ₂	902.4	-14.55	887.85	60+s	2306.3	-62	2307.98	1	2.5995	
	+C										
"	"	"	"	"	?	2310.9	"		2		
133	"	"	"	"	56+s	2304.1	"	2304.13	1	2.5951	
"	"	"	"	"	57+s	2305.4	"		2		
40	A	902.43	"	887.88	85+s	4703.	"		1		
"	"	"	"	"	106+s	4724.2	"	4712.98	2	5.3080	
133	"	902.4	"	887.85	82+s	4704.2	"		1		
"	"	"	"	"	85+s	4707.0	"	4704.98	2	5.2991	
40	A+C	902.35	"	887.8	1146+s	9149.5	"		1		
	-2M										
"	"	"	"	"	1227+s	9233.5	"	9190.88	2	10.3515	
133	"	902.4	"	887.85	1170+s	9171.7	"		1		
"	"	"	"	"	1194+s	9191.7	"	9181.08	2	10.3395	
40	A+C	902.35	"	887.8	111+s	2550.9	"		1		
	+2M										
"	"	"	"	"	146+s	2556.4	"	2553.03	2	2.8716	
133	"	"	"	"	38+s	2548.7	"		1		
"	"	"	"	"	38+s	2548.7	"	2548.08	2	2.8701	
40	A+C	902.6	"	888.05	123	5852.	"		1		
"	"	"	"	"	169	5898.	"	5880.13	2	6.6225	
133	"	"	"	"	134	5863.5	"		1		
"	"	"	"	"	140	5869.	"	5865.63	2	6.6054	

The above results show to what accuracy self-inductances of different values can be compared to each other, or to one of the self-inductances taken as a standard. The reason that the agreement between the different determinations is not greater than it is, even though the electro-dynamometer was sensitive to a change of 1 part in 10000 in $R+r$, is that there was always some little heating of the resistances, and although they were measured in each determination on a Wheatstone bridge, still it was impossible to determine the exact resistance at the time that the experiment was made. This slight effect of the heating of the resistances would not enter in the comparison of two nearly equal self-inductances, that is the comparison of a coil with a standard. The accuracy of this comparison can be made to depend on the accuracy with which $R+r$ can be determined for zero deflection, and this can be done to about 1 part in 10000. To do this, first the standard coil and the coil to be compared are substituted in turn in place of L in figure; they are thus compared separately to a third coil. But as the standard and the coil to be compared are nearly equal in self-inductance, the difference or self-inductance can be determined by the amount necessary to change $R+r$, and this change will be nearly independent of the slight heating of the resistances. To make a coil of the same self-inductance as the standard, the standard is placed in the $R+r$ circuit and the value of $R+r$ is found that produces no deflection. The coil to be compared is then substituted in place of the standard keeping $R+r$ fixed,

and the self-inductance of this coil is changed until there is no deflection, as in the case of the standard. The accuracy with which this can be done depends on the accuracy with which $R+r$ can be set or 1 part in 10000. This method therefore gives a means of comparing and constructing coils to agree in self-inductance to within 1 part in 10000 with a standard.

Method 6. Zero Method for the comparison of Self-inductance with capacity.

9.



This method resembles Method 12 and the connections are made as in the figures when both the hanging coil and fixed coils of the electro-dynamometer are shunted off the main circuit.

Let the currents be denoted by $C_0 \epsilon^{ibt}$, $C_1 \epsilon^{i(bt+\phi_1)}$, $C_2 \epsilon^{i(bt+\phi_2)}$, $C_3 \epsilon^{i(bt+\phi_3)}$, and $C_4 \epsilon^{i(bt+\phi_4)}$. The resistance by R'' , r' , R and r . The capacity by C . The self-inductance by L . A' and A'' are reversing commutators and F the terminals of the fixed coils and H the terminals of the hanging coil of the electro-dynamometer.

If now a periodic electromotive force is applied to the terminals A and B the equations connecting the different currents are as below, from which equations the quantity $C_1 C_3 \cos(\phi_1 - \phi_3)$ is to be found, which is proportional to the deflection. From the figure

$$C_4 \epsilon^{i(bt + \phi_4)} r' = C_1 \epsilon^{i(bt + \phi_1)} \left(R'' + \frac{1}{ibc} \right)$$

$$C_4 \epsilon^{i(bt - \phi_4)} = C_6 \epsilon^{ibt} - C_1 \epsilon^{i(bt + \phi_1)}$$

$$\therefore C_6 \epsilon^{ibt} = C_1 \epsilon^{i(bt + \phi_1)} \frac{R'' + r' \frac{1}{ibc}}{r'}$$

In the same way it is found that

$$C_6 \epsilon^{ibt} = C_3 \epsilon^{i(bt - \phi_3)} \frac{R + r + ibL}{r}$$

$$\therefore C_1 C_3 \epsilon^{i(\phi_1 - \phi_3)} = C_3^2 \frac{(R + r)r' + ibLr'}{R'' + r' + \frac{r}{ibc}}$$

Therefore the real part is

$$C_1 C_3 \cos(\phi_1 - \phi_3) = C_3^2 \frac{(R + r)(R'' + r')rr' - \frac{L}{c} rr'}{(R'' + r')^2 r^2 + \frac{r^2}{b^2 c^2}} \quad a D$$

where D is the deflection. When D is equal to zero

$$(R + r)(R'' + r') - \frac{L}{c} = 0$$

or

$$\frac{L}{c} = (R'' + r')(R + r)$$

In the experiments by this method the $\frac{1}{3}$ microfarad Elliott condenser was used, and it was compared with the different coils P₁, P₂, A, and C. The connections were made with open leads and open resistances were used as far as possible, but it was necessary to use resistance boxes for the last adjustments. The connections having been made as in figure, the process of experimenting was to keep r and r' constant and to adjust R'' and R until there was no deflection of the hanging coil. The resistance of the circuits $R'' + r'$ and $R + r$ were then measured on a Wheatstone bridge. The commutator A' was reversed and the process was repeated. The condenser had absorption (see p. 45) which caused the resistance $R'' + r'$ to be increased by 7.11 ohms. When the capacity is calculated, taking into account the absorption, it is called the corrected capacity, as in the other tables of the paper.

COLLECTED RESULTS.

Coils.	$n=40$.	Results found	Results found	$n=133$.
	Results found by direct measurement.	by taking sum diff., etc., of separate meas.	by direct meas. of coils and combination of coils.	Results found by taking sum and diff. of separate measurements.
P_1	·5664	·5663	·5653	·5648 $(C+P_1)-C=P_1$
"		·5734		·5730 $(C+P_1+P_2)-(C+P_2)=P_1$
P_2	·7251	·7211	·7233	·7187 $(C+P_2)-C=P_2$
"		·7282		·7269 $(C+P_1+P_2)-(C+P_1)=P_2$
C	1·3050	1·3049	1·3034	1·3029 $(C+P_1)-P_1=C$
"		1·3010		1·2990 $(C+P_2)-P_2=C$
"		1·3010		1·3065 $(C+P_1+P_2)-P_1-P_2=C$
A	5·3080	5·3175	5·2991	5·3022 $(A+C)-C=A$
P_1+P_2		1·2945		1·2917 $(C+P_1+P_2)-C=P_1+P_2$
"		1·2915		1·2888 P_1+P_2
$C+P_1$	1·8713	1·8714	1·8683	1·8677 $C+P_1$
"		1·8744		1·8718 $(C+P_1+P_2)-P_2=C+P_1$
$C+P_2$	2·0261	2·0331	2·0221	2·0298 $(C+P_1+P_2)-P_1=C+P_2$
$C+P_1+P_2$	2·5995	2·5965	2·5951	2·5920 P_1+P_2+C
$A+C$	6·6225	6·6130	6·6054	6·6025 $A+C=A+C$

In Method 12 connections due to the hanging coil and fixed coils were calculated so that the ratio of the resistances would give the ratio of the self-inductances direct. In this method (6) since the capacity was in circuit with the hanging coil, the self-inductance was so small that it was neglected. The self-inductance of the coils P , etc., which were joined in circuit with the fixed coils, were increased by the self-inductance of the fixed coils, that is by ·0164 henry.

The table below give the various results.

N.	Coil.	$R''+r$.	Queen in current with		Product.	Position of		C.	Cor. C.
			$R''+r$.	$R+r$.		A' .	L .		
40	P	2008·	205·	1095·7	2198522·	1	·7251 ·0164	·3373	
"	"	2005·	200·	"		2	·7415		
133	"	2024·5	221·	"	2218792·	1	·7233		
"	"	2025·5	222·	"		2	·0164 ·3397	·3330	·3323
40	A	12741·5	30·	1241·85	15922394·	1	5·3080		
"	"	"	30·	"		2	·0164 5·3244	·3344	
133	"	12720·	236·	"	15775610·	1	5·2991		
"	"	12716·	220·	"		2	·0164 5·3155	·3368	·3363
40	C	3430·8	98·	1140·8	3911004·	1	1·3050		
"	"	3425·8	93·	"		2	·0164 1·3214	·3379	

N.	Coil.	Queen in current with		R + r.	Product.	Position of		C.	Cor.
		R' + r.	R'' + r.			A'.	L.		
133	C	3448.8	106 + s	1140.8	3933354.	1	1.3034		
"	"	3447.0	105 + s	"		2	.0164	.3355	.3346
							1 3198		
40	P	1578.5	57 + s	1088.9	1718719.7	1	.5653		
"	"	1578.4	58 + s	"		2	.0164	.3384	
							.5817		

This method can be used with great accuracy for the comparison of the capacity of a condenser with a standard condenser. In the comparison, first one condenser and then the other would be placed in the $R + r$ circuit. If the two condensers are of nearly the same capacity, the degree of accuracy of the comparison depends upon the accuracy with which $R'' + r'$ can be set. The degree of accuracy of setting $R'' + r'$ varies with the value of the self-inductance with which the condensers are compared. In the experiments just given, using the different coils, the degree of accuracy with which two $\frac{1}{3}$ microfarad condensers could have been compared would vary from 1 part in 2000 to one part in 14000. The two condensers are supposed to be without absorption, as its presence would cause trouble unless the absorption resistances were known.

Résumé.—Summing up the results deduced in this paper, it is seen that the methods for the absolute determination of self-inductance and capacity do not give as concordant results as could be wished. The irregularity of results was caused, in the most part, both in the determination of self-inductance and capacity by the variation of the periods of the currents used in the experiments. As the period enters directly into the determination of self-inductance and capacity, all variations of the period will appear in the results. The determination of capacity is complicated by the presence of electric absorption (pp. 44 and 45). The effect of electric absorption is shown to be that of an added resistance in series with the condenser, called absorption resistance. A direct method is given by which absorption resistance can be measured (p. 41), and experiments are given which show that when condensers possessing absorption are in series or in parallel, their absorption resistances act under these conditions as ohmic resistances in series with the separate condensers (p. 45). Absorption resistance is also found to be extremely sensitive to temperature.

The methods for the comparison of two self-inductances or a self-inductance and a capacity are independent of the period, and when the self-inductances are of different magnitudes the comparison can be made with an accuracy of 1 part in 10000. These methods, therefore, give a means of comparison of a self-inductance with a standard self-inductance, or a capacity with a standard capacity to an accuracy of 1 part in 10000, or they allow the establishment of standards.

ART. VII.—*Reflection of Hertzian Waves at the Ends of Parallel Wires*; by LEE DEFEST.

SINCE the famous experiments of Hertz on electric waves in wires, investigators in this field have found most useful the arrangement known as the Lecher system, or adaptations of this. In its original form this consists essentially of two condensers, each of two metal plates, hung parallel. One pair of these is connected to the secondary terminals of an induction coil, with a spark gap in the circuit. From the other pair of plates lead off two long parallel wires.

By the action of the coil the primary plates are charged with equal and opposite quantities of electricity, which discharge across the gap, when the tension has been raised sufficiently high. Rapid oscillations of a period depending on the capacity of the entire system are thus set up, which induce corresponding impulses in the secondary plates. Electric waves surge over the two wires, to be reflected at their ends with a change in intensity and phase depending on the nature of the terminal arrangement.

Thus standing waves are set up in the wires, which are the better defined, the more nearly the length of the wires approaches an integral number of half wave-lengths.

The ease with which these standing waves can here be measured, and the symmetry and simplicity of the whole arrangement, make this system of the greatest usefulness in all researches where the phenomena of waves in wires are to be studied.

At the nodes of these standing waves, a conducting body, as a wire bridge, may be placed across both wires without interfering with the action beyond.

At an other point, however, such a bridge harms the effect, producing extinction of the glow in a vacuum tube placed across the two wires at their ends.

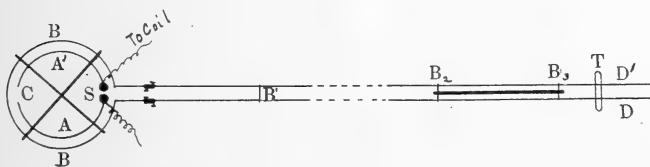
By such means Lecher was enabled to measure readily half wave-lengths, between successive bridges; and inasmuch as theory has shown the velocity of propagation in such a system to be that of light, he could compute the period of the vibration.

With such an apparatus, or with the improved form introduced by Blondlot, an enormous amount of work in determining dielectric constants, indices of reflection, electric dispersion, etc., in fluids, has been accomplished, notably by German physicists. Quantitative experiments have been made with bolometer, electrometer, or thermo-electric means, and thus the attenuation and curves of the standing waves determined.

It was observed that reflection with change of phase occurred at any bridge, bend, or sudden change in the nature of the parallel wires. The mathematical theory for such phenomena has been considerably developed, notably by Drude.*

Theory shows that the waves are reflected at the open ends of the parallel wires without change of sign of electrification. The first node, therefore, would be expected at one quarter of the wave-length from the ends. If capacity of any sort is attached to the ends, however, a change of phase would occur by the reflection and this node be found nearer the ends, by an amount depending on this capacity. Even for bare ends, where no capacity has been assumed, it was early noticed that a change of phase did occur; that the distance to the first node was unexpectedly small.

1.



To investigate this part of the subject was the aim of the experiments described in this paper.

The form of exciter adopted was a compromise between the Lecher and the Blondlot forms. In the latter two pieces of wire, bent semi-circularly, take the place of the primary condenser plates of the Lecher system. To one end of each wire is fastened a small polished zinc ball, forming the spark gap. To the other ends are often attached a pair of metal plates, placed oppositely, to add capacity to the whole.

Outside of the approximate circle thus formed is bent a single wire for the secondary. Its two ends are brought near together, and from these lead out the long parallel wires.

This Blondlot system has a greater damping than the Lecher. Its individual period is less marked, and the frequencies of the waves found upon the parallel wires are almost altogether dependent upon the vibrating systems there formed by bridges arbitrarily located. A great advantage resulting is that a large range of wave-lengths may thus be had from one oscillator.

In the exciter used throughout, instead of wires, two narrow zinc plates, A A', each 15^{cm} long, 1.5^{cm} wide in the middle, and *elliptical* in shape, formed the primary. These were bent as shown in Fig. 1, and each carried a zinc ball, 8^{mm} in diameter,

* Wied. Ann., lii, p. 499; liii, p. 751.

centered at a focus of the ellipse together with the leading-in wires. Thus reflections from every part of the edges of the plates were concentrated simultaneously at the gap.

The spark gap between these two balls varied from 1^{mm} to 2^{mm} . About this primary oscillator a similar zinc strip 32^{cm} long was bent to form the secondary. The whole was immersed in a glass vessel containing kerosene oil. But 0.5^{cm} separated the primary from secondary, and without the oil violent spark discharges passed between all parts of the system. The petroleum was decomposed by the electrical action, carbon being deposited upon the zincs. This oil was renewed from time to time.

This particular arrangement combines advantages of both the Lecher and Blondlot exciters. By the use of plates all the elements of the primary and secondary may be brought closer, the loss of energy found in the Lecher exciter obviated; and the uninterrupted form of the secondary connects the two parallel wires as in the Blondlot, allowing perfect reflection or interchanging of the back-coming waves from DD' . Moreover, the damping of this oscillator was such that its individual period had little effect upon the resonator system of the wires. I could by judicious bridging get almost any wave-length from 50^{cm} to 3 meters. The case was analogous to that of any acoustic vibrating system when struck by a body of any period whatsoever—the primary oscillation caused by the spark discharge serving merely to excite surgings in DBD' , the period of which is determined by the location of the first bridge on DD' .

When the length of the wires DD' is properly proportioned to the period of the exciter, we have of course the strongest possible action. With a first bridge at 36^{cm} from S , and succeeding ones $43\text{--}44^{\text{cm}}$ apart, the vacuum tube, laid across the ends of the wires to serve as a detector, was found to glow with eight bridges on the wires.

For any other wave-length so great a number of bridges quite extinguished the effect of the primary vibrations. I regarded then $86\text{--}88^{\text{cm}}$ as the primary wave-length; the natural period, calculated,* is 60^{cm} in oil, giving 86.4^{cm} in air.

A certain dim glow persisted in the tube, no matter how many bridges were on the wires or where placed. This was found due to the oscillations of the coil, of enormous wave-length, and relatively gradual, unreflected by any form of bridge used, whereas the shorter ones due to the sudden oscillations across S are cut off very sharply. With practice there was no difficulty in distinguishing the different characters of the glow produced by these Hertzian oscillations.

To allow of work in daylight this vacuum tube was completely enclosed in a light-tight box, and viewed through a slot and

* By Drude's method, Wied. Ann., lv, p. 634.

eye-shade. Then by means of an endless cord passed through two pulleys and running below the wires, the observer stationed at the tube could slide a bridge, attached to the cord by wooden clamps, along the wires.

When a node was located by this means, the place was marked, a new bridge hung there, and the sliding bridge then moved farther along the wires. On each bridge was hung a wooden block to hold it fixed in place and in good contact. To facilitate measurements a long scale-piece, graduated in half-centimeters, was below the wires, and the intervals between bridges read therefrom by means of a sliding index arm.

For the purposes intended the vacuum tube was the best indicator known, though but roughly quantitative. To reduce the deforming effect on the standing waves from its capacity to a minimum, no electrode nor tinfoil was used, the bare tube being laid across the parallel wires. Even then it possessed a capacity, as found by a long series of measurements, equivalent to a length of 4^{cm} of the line. This was independent of the wave-lengths used, and was thereafter allowed for in all measurements of wave-lengths where the tube was present.

Relation between Change of Phase in Reflection from Open Ends, and the Frequency.

When an electric wave passes along a conductor we have at any point this relation between the E. M. F. and current :

$$-\frac{d\phi}{dx} - L \frac{dC}{dt} = RC$$

where ϕ = Electro-static potential

C = Current

R = Resistance of the circuit per cm.

L = Self-induction " " "

Let S = Elect. static capacity " "

Q = Quantity of electricity per unit length.

Then $C = Q \frac{dx}{dt} = Qv$ where v = the velocity of propagation.

$$\therefore C = S\phi v$$

$$\therefore \frac{d\phi}{dx} + LSv \frac{d\phi}{dt} + VRS\phi = 0$$

When and where $\phi = 0$ we have*

$$\frac{\delta\phi}{\delta x} + LS \frac{\delta\phi}{\delta t} = 0 \quad (1)$$

* Barton, Proc. Royal Soc., vol. liv, p. 87.

$$\text{or } \frac{\delta\phi}{\delta t} \frac{\delta t}{\delta x} + \text{VLS} \frac{\delta\phi}{\delta t} = 0$$

$$\therefore \frac{\delta\phi}{\delta t} \left[v\text{LS} - \frac{1}{v} \right] = 0$$

whence $v = \frac{1}{\sqrt{\text{LS}}}$ or $Lv = \frac{1}{Sv}$, the well-known Thomson formula for the velocity of the propagation of the wave.

Now the capacity per unit length of the normal part of the Lecher parallel wires is given* very closely by the form

$$S = \frac{1}{4 \text{ Log nat } \frac{d}{r}}$$

in electro-static units, where r = radius of the wires, d their distance apart.

In the wires used $r = .37^{\text{mm}}$; $d = 1.7^{\text{cm}}$. Also $L = 4 \text{ Log nat } \frac{d}{r}$ in electro-magnetic units. Thus the period of Lecher's system, as well as for circular or rectangular resonators, is independent of r or d . And if the resistance is negligible compared to $2vL$ (which is the case for wires greater than 0.5^{mm} diameter or thereabouts, and less than 100^{m} long), the velocity of propagation thereon is that of light. Especially at the point of reflection the resistance R may be neglected. Equation (1) becomes

$$v \frac{\delta\phi}{d\gamma} + \frac{\delta\phi}{dt} \quad \text{and its solution:}$$

$$\phi = f_1.(nt - \beta_0 x) + f_2.(nt + \beta_0 x)$$

where $\frac{n}{\beta_0} = v = \frac{1}{\sqrt{\text{LS}}}$ and $f_1; f_2$ denote any functions (in our case sine functions) with coefficients for the various amplitudes, and a third term in the parentheses to allow for change of phase. So for the original and reflected waves, where $x = 0$ write:

$$V_1 = \phi \sin \left(nt - \frac{\delta_1}{2} \right) \quad (2)$$

$$V_2 = \phi' \sin \left(nt + \frac{\delta_1}{2} \right)$$

where δ_1 is the angle of change of phase in reflection.

* e. g. Lord Rayleigh, Phil. Mag., August, 1897.

But we must consider the case of a condenser, of capacity S_1 between the ends of the two parallel wires. Then if V denote the resultant potential-difference in the wires at the ends from incident and reflected waves, and C the resultant current, we have the condenser equation

$$\frac{\delta V}{dt} = \frac{C}{S_1} \quad \text{if there is no transmitted}$$

wave; and b , the coefficient of reflection, equals 1.

But in the case of open ends we must suppose a part of the energy radiated off, either in expanding, approximately spherical, waves, or for a distance as a beam, more or less plane polarized. The amount lost will be greater the less the capacity of the end condenser.

But for our purpose it is unnecessary to determine the exact course or nature of the wave after leaving the wires. We may consider the case as though the wires were continued past the end condenser, by a pair having a different capacity S_3 per unit length.

Let e_1 be the charge on unit length of the wires due to the incident wave; and e_3 the charge per unit length carried off, with the same velocity v .

Then we may write:

$$C_3 = e_3 v = c e_1 v = g e,$$

where c = coefficient of transmission, and $g = cv$.

$$\text{Now } e_1 = \frac{C_1}{v} \text{ and } C_1 = \frac{V_1}{Lv}$$

$$\therefore C_3 = c C_1 = c V_1 S v$$

Corresponding to the condenser equation we now have

$$\frac{dV}{dt} = \frac{C_1 + C_3}{S_1} = \frac{C}{S_1} + \frac{c V_1}{S_1 L v}$$

Let $\gamma = \frac{S_1}{S}$, the ratio between the capacities of the end condenser and that of a unit length of the line.

$$\therefore \frac{dV}{dt} = \frac{C}{S_1} + \frac{g V_1}{\gamma}; \quad V = V_1 + V_2 \quad (3)$$

Substituting in this the values given for C and V_1 , and developing the equation, we get, letting $t = 0$,

$$n(\phi + \phi') \cos \frac{\delta_1}{2} = - \frac{\phi \left(1 + \frac{g}{\gamma} S_1 L v\right) + \phi'}{S_1 L v} \sin \frac{\delta_1}{2} \quad (4)$$

Letting $nt = \frac{\pi}{2}$,

$$n(\phi - \phi') \sin \frac{\delta_1}{2} = \frac{\left(1 + \frac{g}{\gamma} S_1 L v\right) \phi - \phi'}{S_1 L v} \cos \frac{\delta_1}{2}, \text{ where } \phi' = b\phi \quad (5)$$

We find that the angle of phase difference may be considered as in the second quadrant, the cosines having negative signs. So here if we write the cosine of eq. (4) = $-\cos$ of (5), and at same time make the coefficient of reflection b of (4) equal $-b$ of (5), we can solve between the two equations.

Hence

$$\tan \delta_1 = \frac{-2LvS_1 nK}{1 - (LvS_1 nK)^2} = \frac{.2K\gamma\lambda}{K^2\gamma^2 - \lambda^2} \quad (6)$$

$$\text{Where } K = \frac{1 + b}{1 + b + \frac{g}{\gamma} S_1 L v}$$

From (6) we get,

$$S_1 = \lambda \frac{S}{K} \left(\frac{\cos \delta_1 + 1}{\sin \delta_1} \right) \quad (7)$$

From this equation the capacity of the terminal arrangement can be calculated from the observed values of S_1 and the wave length λ used.

For λ large compared to γ (as was the case for the wave-lengths used) K is nearly unity for $b = 1$, and for b as small as 0.7, $K = \frac{17}{14}$ only. K is taken as unity throughout.

The value of $S = \frac{1}{L}$ calculated for the parallel wires is .067 C. G. S. units. For these wires and frequencies any correction terms for S or L , as by Rayleigh's or Heaviside's formulæ, are absolutely negligible, although the resistances for these oscillations are not at all the same as for steady currents.

Formula (7) was applied to the determination of end capacities for the wire ends bare, and again carrying two brass balls, and under varying conditions, for wave-lengths ranging from 60 to 170 centimeters.

The indicator tube was placed across the wires, generally in the second loop from the ends, sometimes in the last (one-quarter wave-length). In the latter position 8^{cm} were allowed for its presence. No bridge could be placed between the tube and the ends in either case, because it was found that the oscillation of any "system" between two successive bridges, was not perceptibly affected by the resonance or non-resonance of

any system *behind* it, but only by those between it and the source.

The half wave-length was fixed by two bridges, at the desired distance apart, attached to a strip of wood and always moved together back and forth along the line. The nodes thus located were naturally broader and less defined than when but one bridge was shifted.

Although the whole range of half wave-lengths was attempted, at intervals of 2.5^{cm} , only a few could be satisfactorily observed. This was due to the necessity for a *double* resonance to secure a glow in the tube. The system defined by the two bridges kept one half wave-length apart must be in resonance both with the end system and with the part in front including the exciter.

Had it been feasible to employ much longer wires, 100^{m} , this necessity would not have existed with the limited wave-trains sent out by the exciter.

Regarding the bare ends as two spheres of the radius of the wires, the static capacity as calculated graphically by the methods of inverse points was found to be

$$S_1 = .45 \text{ C. G. S.}$$

Thus the actual capacity for the bare ends, for these rapid oscillations, is seen to be very much greater than that calculated for static charges, and varies with the frequency. The curves in Fig. 2 show a slight decrease in the change of phase by reflection with increasing frequency, and a more marked falling off in the end capacity. This decrease in capacity with period is to be expected.

With two brass balls on the ends, 1.85^{cm} diam., 2.55^{cm} between centers, the lost length in reflection is of course much more marked. The extreme limits of the balls were here taken as marking the end of the wires.

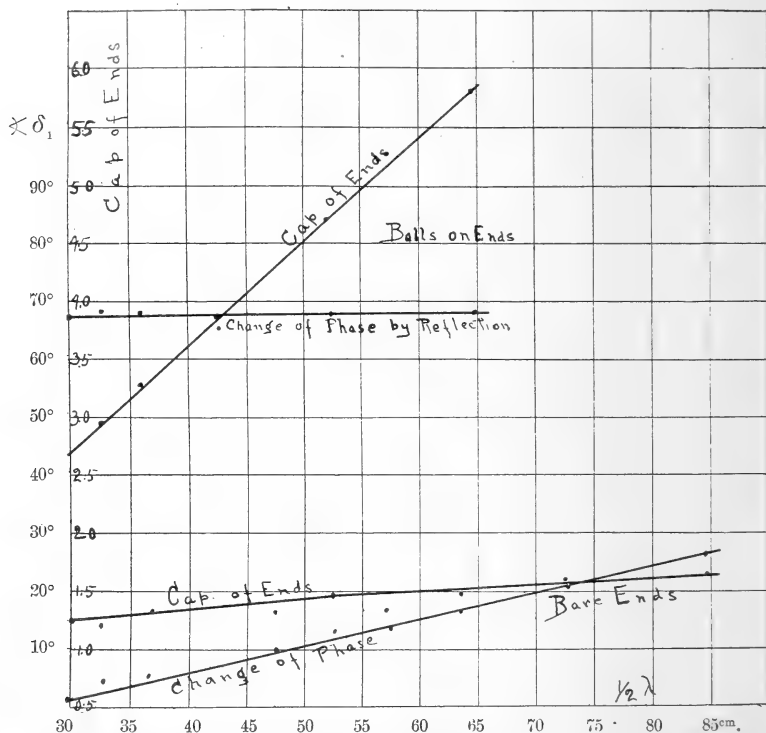
The reflection throughout seemed much better for these balls at ends than for bare ends; the nodes were always more easily located and clearly defined. There was no difference in the character of the reflection with the bare ends, whether these were cut off square or tapered to fine points.

By Maxwell's method the calculated static capacity of the balls is 1.15 C. G. S. units. The observed capacities for these oscillations are from 2 to 5 times greater than this—a much smaller discrepancy than for the case of bare ends. The radiation from the balls is much less.

In the curves given the figures for amounts lost in reflection cannot be defined closer than $\pm 0.5^{\text{cm}}$, because of the broad nodes found, allowing an error of from 2 to 4 per cent in the angles of change of phase.

As to the reflection from rectangular bends in the wires :—so long as the two wires were kept parallel, there was no precep-

2.



Abscissas represent half wave-lengths, ordinates change of phase by reflection, and capacity of ends.

tible difference or change in the angle of phase. Such corners did not therefore affect to any observable extent the capacities of the end systems, for any frequencies used.

But when the wires were bent out from each other the clearness of node was very much impaired—the greater the angle the less sharp the definition—due to the double reflection then existing.

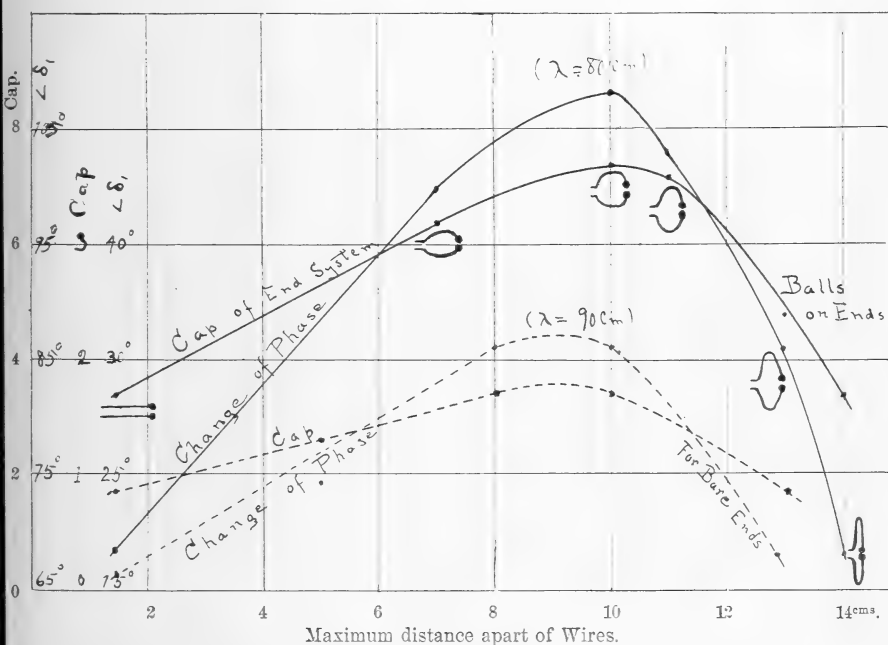
If the distance between the ends, bare or with balls attached, is kept fixed and a certain section of the wires next adjoining is bent out, from straight and parallel wires into curved or circular forms, the last quarter wave-length is observed to shorten, then increase again. The capacity of the section is changed, until when at last the wires are bent out and back, as in (a), Fig. 3, the capacity may be less than for the

original parallel wires; passing through a maximum when the circular form (b) is taken.

In this case the area also is a maximum.

The same phenomenon was observed for bare ends as for the two balls, though again less pronounced; for a longer section of the wires thus bent the effect is still more marked.

In fig. 4 is shown this relation between the form of the ends and the change in capacity and phase.



Now when such convex bends are put into the parallel wires distant from their ends, the effect is the reverse. Von Geitel* found that they produced a decrease in the capacity of the wires at the point, (as is to be expected from the expressions for the capacity), causing a reflection of the same sign as would a change in wires from thick to thin. By bending the wires in he obtained the opposite reflection. So here it is evidently connected with the terminals. The change of phase is maximum when the ends are close together and still as far removed as possible from the influence of the leading-in wires.

* Wied. Ann., xlix, p. 184.

A peculiarity noticed in the action of the tube was its sluggishness in responding to the waves, it seeming to require at first a strong excitation to enable it to respond to weaker. At the start all bridges were removed before a glow would result. The gas seemed to require a "warming up"—its particles violently excited electrically—before weaker discharges passed.

It was noticed also that if the hand was placed on the wires anywhere, even behind the tube, all glow ceased. The same occurred if the wires were grounded, or a very large capacity attached. Yet here the tube was subjected at least to the incident wave, and theoretically, since a large capacity on both wires is like a no-resistance bridge, there should be also perfect reflection and standing waves. But the action is as though due to free electricity on the wires. Grounding at any point keeps its potential zero, and a heaping-up of the charges on the wires is impossible. With the electrometer also, no deflection was possible so long as a large capacity was attached to the parallel wires.

The electrometer used carried, suspended by a glass fiber 25^{cm} long, a needle consisting of two small aluminum disks, moving in the horizontal plane. Parallel to, and a few millimeters above each end of this needle, was fixed a similar disk, connected by fine wire to one of the parallel wires. The whole was suspended in a vessel of albolene oil. This liquid answered admirably, affording the right damping quality and dielectric strength.

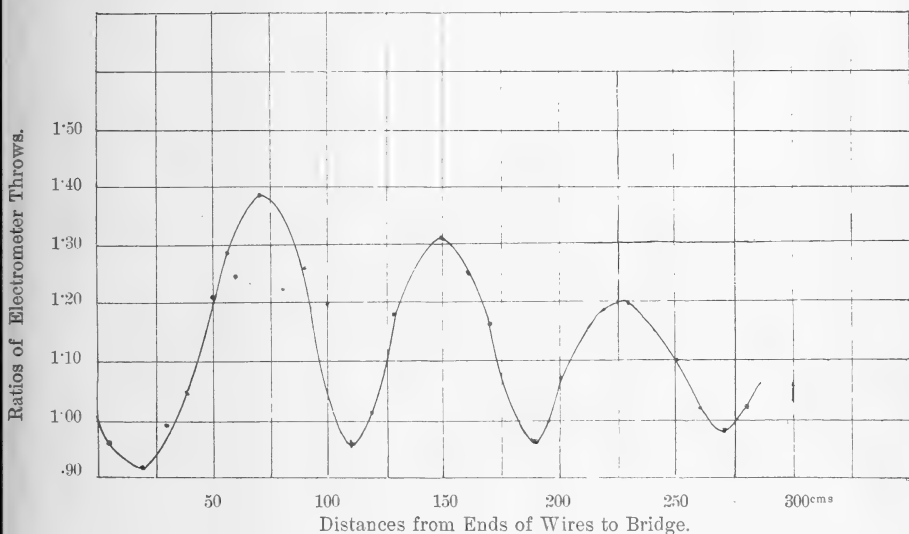
From the center of the needle a fine platinum wire dipped into a small cup of mercury, connected by wire to some capacity. It was found that the deflection was much increased by this, being maximum when the needle was grounded. The sensitiveness of the instrument could thus be directly regulated, and when this leading-out wire was insulated the deflection of the needle charged by induction was almost nothing.

A mirror and scale were unnecessary. A light index arm of glass, 8 inches long, was attached to the upper end of the wooden axis of the needle, where the same joined the glass suspension fiber, above the surface of the oil. This index moved over the face of a mirror scale carrying 120 divisions. The zero was very constant.

For its best working the electrometer did not require the amount of energy in the spark discharge that the glow-tube demanded. The zinc ball gap was made very short, as well as the auxiliary spark gap between the coil and exciter; and the spring interrupter of the coil was adjusted to give as nearly as possible a continuous passage of sparks. The surfaces of this break were kept constantly smooth, as the slightest falling-off of the interrupter, even though unnoticeable to the ear, was at once evidenced by failure of the high-frequency waves.

The decrement of amplitudes in each train of waves here sent out is found to be such that the standing waves created decrease rapidly with increasing distances from the reflecting body. This decrement completely over-masks, in copper wires, that due to attenuation along the wires, for the lengths considered.

5.



This electrometer gave the accompanying curve, fig. 5, similar to those observed by Bjerknes, Barton, and others. As it was impracticable to move the electrometer along the wires the following method was used:—Wires 9.6 meters long were employed and the instrument stationed 4.5 meters from the end. One no-resistance bridge was placed across the wires at a point three-fourths of a natural wave-length beyond the electrometer. This was alternately raised and lowered, so that reflection alternately occurred from it and from a similar bridge moved along the line towards the ends.

The action of the coil is at best so irregular that measurements must be made as nearly simultaneously as possible. First throws of the electrometer needle were read, as much more satisfactory and regular than mean deflections. From 30 to 40 *good* alternate readings were taken for each position of the sliding bridge; the mean ratios of the swings for the two bridges give the relative amplitudes of the two waves. These ratios are plotted as ordinates, and the distances of the sliding bridge from the electrometer as abscissæ. As the distance

between the two bridges decreases the discrepancies between throws are seen to diminish, approaching zero. The effective length of the wave-train is about 8 meters.

From this curve the exponential decrement of amplitudes is found to be $\alpha = \cdot 00095$ per cm.

Experiments with the Coherer.

A coherer was used in looking for polarization in the field near the wires. A glass tube half filled with coarse copper filings was placed in the nose of a large zinc funnel, soldered into the side of a tin box. The galvanometer, dry cell, and a graphite resistance of some 150,000 ohms, were shielded in this, leaving only a small aperture through which to read the mirror. Thus protected the coherer responded only to the waves from the parallel wires placed near.

Three gratings were tried: one made of half-inch strips of zinc, alternating with paper; the second, of lengths of insulated copper wire 3^{mm} in diameter, placed as closely as possible; the third, of wires 0.6^{mm} diameter, strung 5^{mm} apart.

Along the length of the Lecher wires absolutely no polarized displacements were found, whether the coherer lay in the plane of the two parallel wires, or in one perpendicular to this and equally distant from both wires—and whether the coherer were close to or far from these. The waves are propagated in approximately circular forms from the wires, with displacements tangentially perpendicular to them; but there are also displacements parallel to the wires from the flow of the currents in them. One at least of these two components will always penetrate the grating.

That the displacements are not radial here is shown by the complete shielding from them afforded by a tin pipe, as large as 3 inches in diameter, fitted on to the end of the funnel. If this extended more than three inches the action was entirely cut off. This amount of protection was necessary, however, to shield the coherer from diffuse radiation.

The coherer was next placed beyond and facing the ends of the parallel wires (8^{cm} apart). Here also at a distance greater than 15^{cm} from the ends the waves were not polarized, and were cut off as before by a long projecting tin cap. When, however, the ends were brought up close to the grating, or about 8^{cm} from the coherer, a very decided polarization was found. The plane of the two wires being horizontal, the galvanometer gave deflections averaging 17 for the grating strips vertical, and none whatever for them horizontal. This was with the first-mentioned analyzer. The second gave average deflections corresponding to 16 and 2 respectively for the two positions;

the third, deflections 23 to 6 respectively. Rotating the first analyzer, the average results shown in the following table were obtained.

Angle of strips from vertical.	Deflection.	Equivalent deflection.	Cosine of angle.
0°	26	1·0	1·0
22·5°	18	·7	·9
45·0	9	·35	·7
67·5	4	·16	·4
90·0	0	·0	·0

Using two gratings, the segments of the one nearest the coherer lying horizontal, and those of the one in front at an angle of 45° to these, an occasional deflection was secured. More often, however, the resolved vertical component from the first was too weak to penetrate the second. With both gratings vertical good deflections were secured.

Thus the earlier assumption that a beam, as it were, of plane-polarized displacement traveled on beyond the ends of the two wires, was justified. It is also shown very strikingly that it is the component *perpendicular* to the elements of the grating that passes through it. At a very little distance from the ends this plane-polarized beam is lost in the expanding (spherical) waves, or in those diffusely reflected.

Very much might be determined as to the exact nature of the field in the neighborhood of the wires by such use of the coherer—devising proper shields, analyzers, resonators, etc., although as now used it is only roughly quantitative.

My best thanks are due Professor Wright, for the facilities of the Sloane Laboratory put at my disposal, and for kindly interest and valuable suggestions throughout the course of this work, and to Prof. Gibbs for helpful advice.

Sloane Physical Laboratory,
Yale University, May 31, 1899.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Peroxides.*—Some further results have been published by MELIKOFF and PISSARJEWSKY in their investigations on peroxides. They have shown that acid peroxides may form salts with alkali peroxides. The resulting soluble salts, such for example as the sodium and lithium salts of peruranic acids, when treated with aluminum hydrate are converted into the free acid and hydrogen peroxide. The insoluble salts, such as the barium salt of peruranic acid, when treated with carbon dioxide, act like barium peroxide; barium carbonate, hydrogen peroxide, and peruranic acid being formed. Acid peroxides RO_4 have been obtained from elements belonging to six groups. The stability of the salts formed by them with alkali peroxides decreases with the atomic mass of the element forming the acid peroxide. With metallic peroxides, strongly acid peroxides do not form salts but decompose them, forming hydrogen peroxide. They assign to the peroxy-acids and the metallic peroxides the constitution $HO-OH$ analogous to that of hydrogen peroxide, as they behave similarly with certain reagents. They yield hydrogen peroxide on treatment with dilute sulphuric acid, but if the acid is concentrated many of them yield ozone. Water decomposes the peroxy-acids as it does the peroxides; sodium perborate for example being partially decomposed into sodium metaborate and hydrogen peroxide. The peroxy-acids also behave like the metallic peroxides when treated with manganese peroxide, oxygen being evolved rapidly in the case of soluble salts and slowly in the case of insoluble ones; the peroxy-acids oxidize alkalis, easily converting them into peroxides.—*Zeitschr. Anorg. Chem.*, xviii, 59–65, 1898.

G. F. B.

2. *On the Preparation of Iron Silicide.*—The fact has been observed by LEBEAU that copper silicide in the melted state dissolves iron silicide very readily. And upon this he has based a method of preparing the latter compound. Commercial copper silicide, coarsely pulverized, is mixed with ten per cent of iron filings, the mixture is placed in a carbon crucible and this is inserted in an electric furnace supplied with a current of 950 amperes at a pressure of 45 volts, for from four to five minutes. A button is thus obtained, white in color and having a crystalline fracture. It is coarsely pulverized and treated with diluted nitric acid, the temperature being raised toward the end. The copper silicide is dissolved and crystals of iron silicide remain surrounded by gelatinous silica. To remove this, the crystals after washing are heated with a solution of caustic soda. Repetition of the treatment with nitric acid and with soda gives the iron silicide pure. It has the composition $SiFe$, thus differing from the silicide $SiFe_2$ prepared by Moissan by the direct union

of iron and silicium in the electric furnace. It is in the form of tetrahedral crystals having a density of 6.17 at 15°. They scratch quartz but not corundum. Iron silicide is not attacked by oxygen or hydrogen at a red heat, but chlorine, bromine and fluorine act upon it at a red heat with incandescence. Mineral acids are without action upon it, but fused alkalis, or a mixture of fused nitrate and carbonate, attack it readily.—*C. R.*, cxxviii, 933-936, April, 1899.

G. F. B.

3. *On an Application of the Equilibrium Law to the Formation of Oceanic Salt Deposits.*—An investigation has been undertaken by VANT HOFF AND MEYERHOFFER for the purpose of determining theoretically from the law of equilibrium the order of deposition of salts in consequence of the evaporation of sea water, with especial reference to the Stassfurt beds. Evidently, the relations of the individual salts present to each other have to be first considered, and the present paper considers the solubility curves of the various hydrates of magnesium chloride at temperatures varying from -33.6° to $+186^{\circ}$, the point when hydrogen chloride begins to be evolved. The complete equilibrium curve for magnesium chloride and water may be divided into the following portions: (1) Stable solution in equilibrium with ice, from 0° to -33.6° ; (2) Stable solutions in equilibrium with the following hydrates, $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_{12}$ from -33.6° to -16.8° ; $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_8$ from -16.8° to -3.4° ; $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_6$ from -3.4° to 116.67° ; $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_4$ from 116.67 to 181° ; $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_2$ above 181° or 182° ; (3) labile solution in equilibrium with $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_6(\beta)$ from -17.4° to -9.6° . Labile continuations of the curves for the hexahydrate and the dodecahydrate can be obtained, meeting at -30° , whilst similar continuations of the ice and octahydrate equilibrium curves cut at -50° . The dodecahydrate was previously unknown and is best produced by cooling a solution containing a little more water than is required for the crystals, to about -20° and then inducing local over-cooling by solid carbon dioxide. The stable and labile octahydrates also previously unknown can be produced in a similar manner by cooling a solution of the composition $\text{MgCl}_2 \cdot (\text{H}_2\text{O})_{11}$. Once formed, the labile hydrate might remain unchanged for a whole day, but its production could not be depended on. The values found for the solubility of the hexahydrate were in general slightly lower than those of other observers, probably owing to more complete freedom from calcium chloride.—*Zeitschr. physikal. Chem.*, xxvii, 75-93; *J. Chem. Soc.*, lxxiv, 564, December, 1898.

G. F. B.

4. *The Spirit of Organic Chemistry, an Introduction to the Current Literature of the Subject*; by ARTHUR LACHMAN. 12mo, pp. xviii + 229. New York (The Macmillan Company).—This book, which is intended primarily as a supplement to text-books of organic chemistry, consists of nine excellent essays upon the development of some of the most important problems of the science. The subjects dealt with are, the constitution of rosani-

line, Perkins reaction, the constitution of benzene, the constitution of acetoacetic ether, the uric acid group, the constitution of the sugars, the isomerism of maleic and fumaric acids, the isomerism of the oximes, and the constitution of the diazo compounds. The work will be useful as a source of information regarding the history and present status of these particular topics, and it will be valuable also in giving the student a clear idea of the objects of chemical research, and arousing his interest in the literature.

H. L. W.

5. *Lehrbuch der Allgemeinen Chemie*. Von Dr. WILH. OSTWALD. Zweiten Bandes, Zweiter Teil: Verwandtschaftslehre. Vierte Lieferung: Bogen 39-52 Mit Figen 71-152. Zweite umgearbeitete Auflage. Leipzig, 1899 (Wm. Engelmann).—Some of the earlier parts of this fundamentally important work have been already noticed in this Journal, and those interested are well acquainted with its scope and value. The present Fourth Part (pp. 625-828) discusses the cases of Chemical Equilibrium of the Second Order. The part following is to contain those of the Equilibrium of the Third and Higher Orders, and with this the second part of the second volume will be brought to a close.

6. *Insulators for Heat*.—Walter Hempel has made a comparison of the relative value of different media for heat insulation, and gives the following table:

Temperatures in the interior of the vessels.

		Duration of time in minutes						
		5	32	58	88	115	160	207
Dry, clean sheep's wool (dried at 100°)	}	-74	-63	-61	-50			
Cotton wool		-76	-63	-56	-43			
Silk		-76	-65	-58	-48			
Moist sheep's wool		-76	-64	-54	-44			
Clean wool, air dried		-77	-74	-64	-55			
Eider down		-78	-76	-67	-66	-49	-33	-17
Vacuum tubes of D. Bender and D. Holbein	} I	-66	-67	-49	-32	-8	+2	+8
Vacuum tubes of D. Bender and D. Holbein		-68	-65	-49	-34	-11	+1	+8
Weinhold-Dewar tubes—Silvered	}	-78	-77	-74	-70	-64	-59	-50

It thus appears that carefully exhausted vessels give a better means of heat insulation than any other means, while partially exhausted vessels are inferior to the other means in the above list.—*Wied. Ann.*, No. 5, 1899, pp. 135-138. J. T.

7. *Optical relations of Gold and Platinum layers*.—This is an examination of the work of various investigators and a study of the best method of making the measures. The author, G. BREITHAUPT, finds that a method by Schmidt permits of the measure of the index of refraction of metals. Gold gives the most constant values, while platinum does not give consistent ones. Mirrors of obsidian proved of value as foundations for the layers. Burned-

in gold showed normal dispersion, while burned-in platinum exhibited anomalous dispersion. Steel and nickel-steel showed anomalous dispersion; brass, highly polished, normal dispersion.—*Wied. Ann.*, No. 5, 1899, pp. 46-73. J. T.

8. *Electrical Waves*.—ALBERT NEUGSCHWENDER has described a new method of detecting electric waves, which consists in using as receiver two pieces of tin foil separated by a fine line. This Rhigi resonator is placed in one branch of a Wheatstone bridge. The fine line is moistened by various electrolytes or by vapors. When the electric waves impinge on the slit its resistance is greatly increased, in some cases rising from 80 to 90,000 ohms. The author has carefully investigated the phenomena, and finds that the waves disturb the formation of fine filaments of metal in the electrolytes (*Metallbäumchen*), which are essential for good conductivity.—*Wied. Ann.*, No. 5, 1899, pp. 92-98. J. T.

9. *Ether Movements*.—G. MIL discusses analytically the question of the fixed and moving ether in relation to Poynting's hypothesis. In order to ascertain a possible limit, he arranged condensers in a powerful magnetic field in such manner that the electrostatic lines of force were at right angles to the magnetic lines, and by means of an interferential refractometer tested whether a light ray suffered any change in velocity. A negative result was obtained. This, according to the author, does not show that the ether is fixed, although the value for μ (inertia of ether particles) was $\mu > 10^{-10}$, which is very small.—*Wied. Ann.*, No. 5, 1899, pp. 129-134. J. T.

10. *Verhandlungen der Deutschen Physikalischen Gesellschaft*.—Physicists will be interested in the announcement recently made by the publishing house of Johann Ambrosius Barth, in Leipzig, that it is proposed to publish the Transactions of the German Physical Society, successor to the Physical Society of Berlin, in successive numbers, published as called for, and for which an annual subscription price of 4 marks will be charged. The first number (pp. 1-48) has already been issued.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey, Eighteenth Annual Report*, 1896-97.—The bound volumes of the Eighteenth Annual Report have been issued in five volumes. Part I, *Director's Report*, including *Triangulation and spirit leveling*, pp. 440. Part II, *Papers chiefly of a theoretic nature*, pp. 653. Part III, *Economic geology*, pp. 861. Part IV, *Hydrography*, pp. 756. Part V, *Mineral resources of U. S. for 1896*. Each of the volumes is illustrated by numerous plates and maps. The contents of the second volume have in part been already noticed in this Journal, as they were issued in pamphlet form. Special notice at this time should be drawn, however, to a few not heretofore mentioned:

The Triassic formation of Connecticut, pp. 1-192, plates 1-20; by W. M. DAVIS.—This is the final report of Professor Davis on the Triassic area, which he has been studying for a number of years, the main facts and theories of which have already become well known to geologists. The final volume is beautifully illustrated, and is particularly valuable for the photographic representations of several contacts between the trap and the sedimentary rocks, and the clear, systematic presentation of the whole subject.

Glaciers of Mt. Rainier, with a paper by G. O. SMITH on the rocks of Mt. Rainier, pp. 349-423, plates lxx-lxxxii; by I. C. RUSSELL.—This is a beautifully illustrated account of a glaciated mountain region in Washington, which presents some remarkable features that should attract visitors and sight-seers, as well as the professional geologists.

Geology of Cape Cod District, pp. 497-593, plates xcvi-civ; by N. S. SHALER.—In this paper Professor Shaler gives, in a graphic manner, an account of the superficial geological structure of the district about Cape Cod, tracing the features back to their supposed causes, viz: glaciation, erosion, etc.

Recent earth movement in the Great Lakes Region, pp. 595-653, plate cv; by G. K. GILBERT.—Mr. Gilbert elaborates some of the later results of his studies of the earth movements as affecting the Lake Regions. He has shown the methods of recording observations, and given comparisons of movements in relation to Lake levels, and has drawn together the various observations and reduced them to a form expressing differential movements of the whole region, estimating the rate and direction of past and present movements. (See this Journal, March, 1899, p. 239.)

In the volume of *Economic Geology* are several very valuable reports. The first two, on the Gold fields of Alaska, respectively by Messrs. Becker, and Spurr and Goodrich, have already been noticed in these pages.

Four other important papers are given: Some Coal fields of Puget Sound, pp. 393-436, plates lli-lxviii, by B. Willis; Geology and mineral resources of the Judith Mountains of Montana, pp. 437-616, plates lxix-lxxxvi, by Messrs. W. H. Weed and L. V. Pirsson; The mining districts of the Idaho Basin and the Boise Range, Idaho, by Waldemar Lindgren; with a report on the fossil plants of the Payette formation, by F. H. Knowlton, pp. 617-744, plates lxxxvii-cii; Preliminary report on the mining industries of the Telluride quadrangle, Colorado, pp. 745-850, plates ciii-cxviii, by C. W. Purrington. w.

2. *Nineteenth Annual Report of the Director of the United States Geological Survey*, 1897-98, CHARLES D. WALCOTT, Director, pp. 1-143, plates i-ii.—The Director's report of operations for the year 1897-98, and contents of the final report, is in hand. The operations of the Survey are a continuation of those of last year, with very slight modification in general. We note a few important results in the course of the report, reported by the

several members of the Survey. The aggregate appropriation for the Geological Survey for this year was a little over one million dollars.

In Mr. Emmons's report on work in the Rocky Mountain Region, the following results regarding the Tintic mining region of Utah are reported:

"Contrary to what is usually the case in Western mining districts, there appears to have been no genetic connection between ore deposition and eruptive action, for it has been proved that the most important ore bodies—viz., those entirely inclosed in sedimentary rocks—were formed and eroded before the igneous rocks were erupted."

"The complete independence of the ground-water level in the mine in sedimentary and those in igneous rocks."

"As a consequence of the depth of the permanent water level in the former mines, their ores have been very largely oxidized, and in this process of oxidation there has been a remarkable separation of the minerals according to their metallic bases, lead ores predominating at one point, copper ores at another, and silver ores at a third."

Mr. Lindgren reports, regarding Surveys in the Snake Valley, the following:

"This reconnaissance was carried on near the line where the great Columbia lava flows rest against the older ranges of granite and slate in the Idaho side, and showed that the cause of the great fresh-water lake was to be found in the immense lava masses barring the comparatively narrow outlet of a wide pre-Neocene valley. It was also found that since Neocene times the Snake and Salmon rivers have cut gorges from 4,000 to 6,000 feet deep through these lava barriers, equaled in grandeur by few canyons of the West." In the Silver City mining district "transformation or pseudomorphism of a primary gangue mineral, probably calcite, to quartz was noted." Also, "quartz deposits were found carrying gold and silver and at the same time including imprints of vegetable organisms—a proof of their aqueous origin."

Mr. Turner finds in the Yosemite region evidence of "two periods of ice expansion, with an interglacial period."

The Director having, in his capacity as inspector of forest reserves in the northwest, made examination of the Yellowstone, recommends, in his report to the Secretary of the Interior, the construction of new roads from the Grand Canyon Hotel, down the river to Yancey's and thence around the Cook City road; and also several horse trails for the convenience of those who would go on horseback off from the traveled road to points of interest. Another important recommendation is that a hotel be built at the Upper Geyser Basin for the convenience of travelers; and another important suggestion that some means be taken to allay the dust nuisance on the traveled roads in the park.

Mr. Day's report on the Division of Mineral Resources shows a grand total of mineral products of the United States for 1897

to be \$632,309,565, "the greatest in the history of the country. A noticeable feature of this remarkable total is the increase in the value of almost all the important metallic products, especially that of pig iron, gold, copper, lead, and zinc, each of the three latter metals reaching their greatest production. Proportionately aluminum made the largest increase, its product being over three times that of 1896 and many times greater than in any year prior to 1895."

W.

3. *Pre-Cambrian Fossiliferous Formations*; by CHARLES D. WALCOTT, Bull. Geol. Soc. America, Vol. 10, pp. 199-244, pls. 22-28, 1899.—Mr. Walcott has brought together in this valuable contribution more information than most geologists would suppose to be in existence regarding clastic formations, clearly pre-Cambrian in position, and yet as clearly of sedimentary origin, and probably fossil-bearing, situated in various regions on the North American continent. The discussion of the section of the Belt terrane in Montana is the result of special investigations of the author during a recent trip in that region. The author has gathered the facts from reports already made by others, bearing on this subject, and in discussing the evidence of fossils in strata determined to be of pre-Cambrian age, makes reference to foreign as well as American evidence. The principal evidences brought forward are the following: Of problematic character is Eozoon, whose organic origin is as yet unproven. The same appears to be true of supposed fossil sponges, described by Matthew, from Laurentian rocks of New Brunswick, and of radiolarians and sponges of Brittany.

Graphite has frequently been cited as proof of the existence of fucoids, and the finest example of bedded graphite in Algonkian rocks referred to is at the mines of Hague, on Lake George, New York, where graphite occurs, presenting the appearance of fossil coal beds, and alternating with sandstones. The graphite shale exists, varying from 3-13 feet in thickness.

The supposed organic origin of Paleotrochis is shown to be erroneous by recent investigations of Mr. Diller, as reported in this Journal (May, 1899, p. 337).

Again, the evidence brought forward by Mr. Gresley, of supposed organic remains in the iron-bearing rocks of the Menominee range, Michigan, and described as actual evidence of life, and other evidence of similar kind in these Upper Huronian rocks, have been shown to be of doubtful value upon minute examination.

The *Aspidella* of the Avalon terrane of Newfoundland is reported by the author as, probably, of organic origin.

The Etcheminian fossils, reported by Matthew, are referred to, without giving judgment in the matter, awaiting the fuller report of the fauna, which is expected soon. Mr. Matthew thinks the fauna contains 20 species.

In the Chuar terrane of the Arizona Grand Canyon series, of established pre-Cambrian age, forms of unquestioned organic origin have been obtained. The one, *Cryptozoon occidentale*, is de-

scribed by Sir Wm. Dawson; the other is described in the present paper under the name of *Chuarina circularis*. Some others, obscure forms, possibly *Hyalolithes*, are associated with them.

The fossils described from the Belt terrane of Montana constitute the more important contributions of this paper. They occur in the "Greyson shales, in a belt of calcareous shales about 100 feet above the Newland limestone, at a horizon approximately 7,700 feet beneath the summit of the Belt terrane at its maximum development. Indications of fossils were first discovered near the mouth of Deep Creek canyon, a short distance above Glenwood postoffice. Subsequently they were found in Sawmill canyon, about 4 miles above Neihart."

"The fauna includes 4 species of annelid trails and a variety that appears to have been made by a minute mollusk or crustacean. There also occur in the same shales thousands of fragments of one or more genera of crustaceans. All the specimens are very much compressed and flattened, and often large fragments of the test have been broken by a movement in the shale subsequent to their embedment in the mud."

"The most interesting feature of the fauna is the occurrence of undoubted organic remains and the presence of a crustacean of a much higher type than most paleontologists would have predicted for this horizon."

Six new species are described from these shales, distributed in three different genera, one of which is a new genus, referred to the *Merostomata*. W.

4. *A Palæozoic Terrane beneath the Cambrian*; by GEO. F. MATTHEW. *Annals N. Y. Acad. Sci.*, vol. xii, No. 2, pp. 41-56, 1899.—This paper describes a series of strata beneath the Cambrian in New Brunswick, Canada, and Newfoundland, which unconformably underlie that system. The terrane in Canada is in the southern part of the province of New Brunswick, and is exposed in certain valleys by the erosion of the Cambrian. It consists of red and green slates and sandstones, with some conglomerate at the base, and intercalated. In Newfoundland at Smith Sound, on Trinity Bay, and elsewhere, a similar series of strata are found; but here the strata are almost entirely red slates, though limestone beds are intercalated.

In the limestones there is found a fauna which has notable points of difference from the Cambrian. No trilobites have been found in it, but the *Hyalithidæ* are especially numerous, and for size exceed all other forms of the fauna. Conical shells resembling *Palæacmaea* and *Scenella* are common, but other *Gasteropods* and the *Brachiopods* are quite small. A small *Lamelli-branch* was found, and a minute crustacean (*Aptychopsis*). Burrows and trails of worms occur. Attention is called to the advanced development of the *Hyalithidæ* which are present in this fauna. It is suggested that some of the red slates near Boston, Mass., may be of this age.

5. *The Islands and Coral Reefs of Fiji*; by ALEXANDER AGASSIZ.—Volume XXXIII of the Bulletin of the Museum of Comparative Zoology at Harvard College has recently been issued, containing a description of the coral reefs of the Fiji Islands by Professor Agassiz, as the result of the investigations begun by him in November, 1897. A paper by the author published in this Journal for February, 1898, gave a summary of his observations, and states clearly the most important point arrived at, namely, his conclusion that the theory of Darwin is inapplicable to these islands. All interested in this fundamental problem will turn with pleasure to this exhaustive monograph, with its beautiful series of one hundred and twenty plates. The earlier of these represent the forms of the islands with their outlying reefs, while nearly one hundred are artotype reproductions of photographs, giving a charming impression of the peculiar features of the beautiful scenery. While this notice can serve only to call attention to the publication of this paper, it may be worth while to quote the concluding paragraph by the author, in which he summarizes the conclusions he has reached:

"My observations in Fiji only emphasize what has been said so often, that there is no general theory of the formation of coral reefs, either of barrier reefs or atolls, applicable to all districts, and that each district must be examined by itself. At least such has been my experience in the Bermudas, the Bahamas, Cuba, Florida, the West Indies, the Sandwich Islands, and Australia. The results of this trip show plainly that Darwin's theory is not applicable to the Fiji Islands, notwithstanding the borings at Funafuti, and that, in all cases I have examined, the reefs form but a thin crust upon the underlying base, the shape and composition of which is not in any way due to the growth of corals of the existing period."

6. *Experimentale Untersuchungen ueber die Bildung der Minerale im Magma von J. MOROZEWICZ*. Tsch. Min. Petr. Mitth., xviii, Nos. 1, 2, 3, 1898.—By their publication in German the important investigations which Morozewicz has been conducting for five years or more and which, as heretofore published in Russian, have been inaccessible to most petrographers and chemists, are now available for use and study.

Not since the now classic studies of Fouqué and Michel-Lévy has so important a work appeared on the formation of minerals in molten magmas. The author obtained the use of a portion of one of the furnaces in a glass factory and was enabled to conduct his experiments under conditions and on a scale which no previous experimenter had been enabled to command. For the actual results themselves the original work must be consulted, they are too numerous and important to admit of mention in a brief notice. Among others, most of the natural lavas, including rhyolite, as well as a large number of minerals, some of them supposedly foreign to igneous magmas, were produced. The minerals of granite rocks, quartz, feldspar and mica, were formed in dry

fusion. Many laws concerning the formation of minerals in certain chemical compositions by fusion are announced. It is a work which should be carefully studied by every petrographer, mineralogist and mineral chemist.

L. V. P.

7. *Kyshtymite and Corundum-Syenite*.—In the work mentioned above MOROZEWICZ describes massive rocks from various localities in the Urals containing corundum. Some of these are corundum-syenites consisting mainly of orthoclase, biotite and corundum—the latter playing the function of quartz in a granite. Some are pegmatitic in character, the well-formed corundum crystals surrounded by orthoclase. Such occurrences must resemble the corundum-syenites of Ontario which have recently attracted much attention. Corundum-syenite-pegmatite occurs also in Montana at an undescribed locality, while Mallet in a recent work (*Records Geol. Surv. India*) describes instances of corundum in syenitic rocks as well as basic ones, and these latter recall the North Carolina localities. The occurrence of corundum as an important constituent of igneous rocks is now not only well confirmed but proving not uncommon.

Morozevicz describes also from the Urals rocks which consist of corundum and biotite with some zircon and spinel and of granitic structure. The alkali feldspars are here replaced by plagioclase and for these plagioclase-corundum rocks he proposes the name of Kyshtymite. It is the source of the disputed barsowite of Rose, which is here shown to be anorthite.

L. V. P.

8. *Le Gabbro du Pallet et ses Modifications*, by A. LACROIX. *Bull. des services Carte géol. de France*, No. 67, vol. x, 1899, 8°, pp 56, Paris.—The author in this work describes a mass of gabbro surrounded by mica schists. It is formed in the main of an olivine-gabbro with labradorite which passes gradually into norite with andesine and cordierite, especially at the borders. It is cut by numerous dikes whose rocks recall those associated with the gabbros of the Odenwald. The chief interest centers in the origin of the norite with cordierite and garnet, and this is believed to be the result of the normal gabbro coming in contact with the mica schists and absorbing them in quantity with consequent change in chemical composition and production of a different mineralogical type.

L. V. P.

9. *Steinbruchindustrie und Steinbruchgeologie*; by O. HERRMANN. 8°, pp. 428, pl. 7. Berlin, 1899.—This work, which is written for those using stone in technical ways such as quarrymen, architects, engineers, etc., gives in a rather simple and elementary manner a description of the chief rock-making minerals followed by an account of the most important rocks from a technical standpoint, the descriptions and classification being based on Zirkel's manual. A considerable amount of geology relating to the subject is incorporated. This is followed by a description of the tools and methods of quarrying and working stone.

The succeeding and larger part of the volume is devoted to a

minute description of the quarries and stone industry of the kingdom of Saxony.

The volume should answer the same purpose in Germany that the admirable hand-books of Merrill have done in this country.

L. V. P.

10. *Studies in the Amphiboles and Pyroxenes*.—Attention must be called to two important articles published by R. A. DALY in the *Proceedings of the American Academy*, volume xxxiv. The first (pp. 311–323) gives a minute discussion, with several plates, of the optical characters in the vertical zone of amphiboles and pyroxenes, showing with this a new method of determining the extinction-angles from cleavage plates.

The second, a larger paper (pp. 373–429, pl. i–iv), takes up the subject of the etching figures of these minerals, particularly those of the amphibole group. The care with which the author has worked out the special conditions necessary to obtain the best results and the fullness with which he describes his experiments, make his paper of great value to all interested in this subject, aside from the conclusions which he has deduced. Among other points he proves that the amphiboles are throughout holohedral. He also shows that this method of investigation serves to exhibit the close relationship existing between the different members of the group, as too between them and the corresponding pyroxenes. Further, it emphasizes the distinction between the non-aluminous and aluminous amphiboles, usually insisted upon in works on mineralogy, and at the same time shows the great importance of a sesquioxide, whether ferric oxide or alumina. In regard to certain members of the amphibole group, the following conclusions are given:

“Glaucophane and gastaldite are the same species, and both isomorphous with hornblende. Arfvedsonite appears to hold a more or less independent place in the family of amphiboles. Barkevikite is more closely related to common hornblende than to arfvedsonite. Anthophyllite and gedrite are plainly orthorhombic and holohedral. Aenigmatite diverges considerably from the amphibole habit, but betrays a tendency toward symmetrical cohesive property, as it does toward crystallographic symmetry.” Incidentally the author has found an amphibole so peculiar in etching figures that he has separated it as a special variety under the name *philipstadite*. (See p. 83.)

11. *Brief Notices of Some Recently Described Minerals*. HARDYSTONITE is a new calcium-zinc silicate from Franklin Furnace, New Jersey, described by J. E. Wolff. It occurs in granular crystallized form, showing several cleavages interpreted as basal and prismatic. Thin sections show it to be uniaxial and negative. Hardness, 3 to 4; specific gravity, 3.396; colorless to white, with vitreous luster. The formula deduced is $\text{Ca}_2\text{ZnSi}_2\text{O}_7$, obtained from a number of analyses, of which one is here quoted.

SiO_2	ZnO	MnO	CaO	MgO	Fe_2O_3	ign.
38.10	24.30	1.50	33.85	1.62	0.57	0.52 = 100.46.

Before the blowpipe it fuses with difficulty to a cloudy glass, giving a red calcium flame; on charcoal it glows and yields a sublimate of zinc oxide; gelatinizes easily with hydrochloric acid. Obtained from the North Hill mine at Franklin, where it occurs in a fine granular banded ore associated with willemite, rhodonite and franklinite. Named from the township in which the locality is situated.—*Proc. Amer. Acad. Sci.*, xxxiv, 479, 1899.

CARNOTITE is a vanadate of potassium and uranium described by C. Friedel and E. Cumenge. It occurs as a yellow crystalline powder, or in loosely cohering masses, easily separated by the fingers; it is intimately mixed with a quartzose sand. The formula given for it is $K_2O \cdot 2U_2O_5 \cdot V_2O_5 \cdot 3H_2O$, deduced from the following analyses (after the separation of silica) of air-dried material:

V_2O_5	U_2O_5	K_2O	H_2O	
20.12	63.54	10.37	5.95	= 99.98
20.31	64.70	10.97	5.19	Fe_2O_3 0.96 = 102.13
19.95	62.46	11.15	—	Fe_2O_3 0.65

Occurs in Montrose Co., Colorado, in cavities or associated with malachite and azurite. Some samples show 60 p.c. of SiO_2 , the purest 2.6 to 7.2 p.c.; separation is accomplished by nitric acid. Named after M. Adolphe Carnot.—*Comptes Rendus*, cxxviii, 532, 1899.

PHILIPSTADITE is a variety of amphibole named by R. A. Daly, and identified by him in the course of an investigation of the etching figures of the amphiboles, which is referred to in another paragraph (p. 82). The locality is Philipstad, Sweden. It shows anomalous etching figures on m (110) and b (010); pronounced zonal structure; small optic axial angle (about 50°); also unusual pleochroism and absorption: viz., **a** light brownish green, **b** dark yellow-green, **c** dark blue-green; $b > c > a$. It is optically —, with an extinction-angle on b (010) with $e = +15^\circ 9'$ (Na). An analysis by Pisani gave:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	ign.
45.20	0.84	7.34	7.55	15.80	1.52	12.30	8.40	0.80	0.37	0.70 = 100.82

—*Proc. Amer. Acad. Sci.*, xxxiv, 433, 1899.

FEDEROVITE is a pyroxene, intermediate between ægirite-augite and ægirite. It is named by Viola in a petrographical article on rocks from the province of Rome, Italy, in which the author makes an extended study of the optical properties of the pyroxenes. In this he shows that they may be classified into groups according to the angle, $c \wedge c$ which angle increases with increasing soda and iron. Of those in which $c \wedge c = 50^\circ - 56^\circ$ and $2V = 50^\circ$ are called ægirite-augite, he thinks that those in which $c \wedge c = 65^\circ - 75^\circ$ and $2V = 50^\circ$ should have a separate name. Such a variety would contain from 9–13% alkali, about 24% iron oxide and strong pleochroism **c** = yellow, **b** = **a** = olive green. The name given above, which is proposed for this variety, is given after the Russian petrographer E. von Federov.—*Jahrb. f. Min.*, i, 120, 1899.

12. *The Characters of Crystals ; an Introduction to Physical Crystallography ;* by ALFRED J. MOSES. Pp. 21, New York, 1899. (D. Van Nostrand Company.)—Professor Moses has here developed and presented in book-form a series of chapters on the Geometrical and Physical Characters of Crystals, the substance of which has already appeared in the School of Mines quarterly. The first part of the work is devoted to the geometrical side, and after a brief historical summary, there is given an account of the general properties of crystals, followed by a discussion of the thirty-two groups divided according to symmetry. Here the order, method and nomenclature of Groth are followed closely. The latter half of the work is devoted to physical characters, those relating to light occupying by far the larger portion of the space. The presentation throughout is concise and in the main simple ; many students will find the work interesting and helpful, for it does not assume a special knowledge of Mineralogy.

III. BOTANY.

1. *Variation under grafting, and the heredity of acquired characters ;* by L. DANIEL. *Ann. sc. nat., April and May, 1899.*—M. Daniel has conducted his interesting studies in regard to the effect of the scion on the stock and the origination of variation thereby, for almost ten years. He has made his work logically comparative, and has, in this way, contributed some very important facts to the literature of the subject. He insists that a broad distinction must be drawn between the behaviour of a cutting and an implanted graft. The former has in the soil the nutritive conditions of its parent ; the graft is tributary at once to the stock in which it is fastened and places it at once under contribution. It is not a matter of parasitism, for the scion, with its leaves, is to aid in providing elaborated matters for the stock, but, nevertheless, it demands crude materials from the soil through and from the stock.

The graft and grafted plant must be regarded as a case under the general law that change of environment may, or rather, must modify form and structure. Variation from grafting is a function of modifications brought about in the general nutrition of the two plants. This modification may be direct as in the case of the somatic union, or indirect as in the instance of the blending of the germ-plasma from two sources. The author makes the statement that the germ-plasma can be affected from the first generation in the graft, contrary to the law laid down by Weissmann.

The graft and stock introduce variations which may be very slight and liable to be overlooked, but carefully considered these variations are seen to be generally conservative. And as the graft can convey in perpetuity an accidental variation, these accidental variations of the second order can themselves be transmitted effectively. If the influence of a graft on a plastic soma

may be strong enough to lead to the origination of a variety, as this research has shown to be possible, we have here in the process of grafting a valuable appliance which is capable of wide utilization in initiating new forms as well as in preserving old ones. The action of grafting on the reproductive elements and on the transmission of these new characters opens up to seed cultivators an inviting field of practice. It must not be overlooked that, as matter of fact, variation does not come in the grafted plants themselves, but manifests itself in the embryo alone. The author emphasizes the importance of this process of grafting in the improvement of sorts, and shows that such work can be carried on with the utmost system. The process is, by no means, confined to woody plants, but, as the investigation shows abundantly, it is applicable to a wide range of herbaceous species. Merely from a utilitarian point of view, the research is a valuable contribution, while regarded from a purely scientific standpoint it possesses deep interest. The work already done is of consequence, but its best service is in opening up new practical questions.

G. L. G.

2. *Researches concerning certain features in the appropriation of nitrogen by plants*; by L. LUTZ. *Ann sc. nat.*, Jan. and Feb., 1899.—After a good, although brief, resumé of the more important studies in regard to the relations of plants to nitrogen, the investigator gives a detailed account of his own researches in one part of the field. His results are claimed by him to prove that placed under as aseptic conditions as possible, and also under conditions which forbid ferment action or the fixation of free nitrogen, phanerogamic plants can borrow from *amines* employed in the form of salts, all the nitrogen which is necessary for their use. And, further, he decides that the assimilation of these substances can take place without having their nitrogen previously brought into nitric or ammoniacal combination. There is, however, a condition requisite, namely: that the *amines* arise from the substitution of hydrogen in radicals which do not possess too great size of molecule; thus, the methylamines are excellent sources of assimilable nitrogen, while benzylamine and pyridine are inadequate. The phenol amines are tonic.

The salts of the compound ammoniums and the alkaloids, employed as the exclusive source of nitrogen, do not furnish enough to plants; on the contrary, plants under these conditions may even lose a part of their initial nitrogen. This loss may be interpreted, according to the author, as due to a sort of auto-fermentation.

One of the most interesting facts noted by M. Lutz is the ready absorption of unassimilable alkaloids in the presence of assimilable nitrogen. Possibly, he says, this may throw light on the cause of the migrations and disappearance of alkaloids in the plant at certain epochs of its life.

The whole series of experiments on three classes of plants, Phanerogams, Algae, and Fungi, shows that these organisms are

capable of appropriating the lower animes as well as the nitrates, and this conclusion is emphasized as explaining the rapidity with which plants can utilize manures. The author points out the difficulty of conducting such experiments on phanerogams, but the results thus far are the same as those obtained by study of fungi, which can be more easily managed.

G. L. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science*.—The preliminary announcement of the forty-eighth annual meeting of the American Association has recently been issued. The meeting will be held at Columbus, Ohio, August 21st to 26th. The several affiliated scientific societies will also hold their sessions in Columbus. The Association headquarters will be located in room 10, University hall, Ohio State University, and the hotel headquarters of the Council of the Association will be at the Chittenden Hotel. The local secretary is Professor B. F. Thomas, Ohio State University, Columbus, Ohio, who should be addressed in regard to all matters relating to local arrangements, transportation, and hotel and boarding-house accommodations, etc.

The Permanent Secretary, Mr. L. O. Howard, of Washington (Cosmos Club, before August 15, after that date A. A. A. S., Columbus), who issues the circular alluded to, will send copies of it to all desiring information in regard to the presentation of papers, the nominations for membership, etc.

2. *Scientia*.—A new series of small volumes on scientific subjects has been undertaken by G. Carré & C. Naud, as publishers, in Paris. It is intended to present in concise form discussions of scientific questions of importance at the present time with the object of aiding the busy reader and worker to keep up with the bewilderingly rapid progress of science.

The series is divided into two parts,—*physico-mathematical* and *biological*. The character of the work that will be done is sufficiently guaranteed by the names of those that appear as directors in the two departments. They are as follows: In the physico-mathematical section:—MM. Appell, Cornu, d'Arsonval, Friedel, Lippmann, Moissan, Poincaré, Potier. Also, in the biological section—MM. Balbiani, prof. au College de France; d'Arsonval, Filhol, Fouqué, Gaudry, Guignard, Marey, Milne-Edwards.

Three volumes have been issued, whose titles are given below. Among others proposed is one on the Zeeman Effect, by A. Cotton; another on the Determination of the Ohm, by G. Lippmann, etc.

The volumes already published are:—

La théorie de Maxwell et les oscillations Hertiennes. H. Poincaré: pp. 80.

La Spécificité cellulaire. L. Bard. pp. 100.

La Sexualité. F. le Dantec. pp. 98.

3. *Annals of the Astronomical Observatory of Harvard College.* Volume XXXIX, Part I. *Peruvian Meteorology*, 1888 to 1890. Compiled and prepared for publication by SOLOMON I. BAILEY, under the direction of E. C. Pickering, Director.—This very interesting volume contains an account by Professor Bailey of the establishment, under the auspices of the Boyden Fund, of a meteorological station on the volcano El Misti, above Arequipa, Peru, at an altitude of 19,200 feet. Professor Bailey's narrative is most entertaining and, in connection with the excellent illustrations, gives those who are not so fortunate as to have had the opportunity to attain such an altitude, some idea of the grandeur of the accompanying scenery. A second chapter discusses the configuration and height of the Andes and a third contains a series of tables giving the meteorological observations made in Peru during the years 1888, 1889, and 1890.

4. *Report of the Superintendent of the United States Coast and Geodetic Survey, showing the progress for the year ending June, 1897.*—The annual report of General W. W. Duffield has recently been issued by his successor, Mr. Henry S. Pritchett. It contains the usual statement of the progress made in the Survey work at different points on the coast, with a series of fifteen charts relating thereto. The second part of the volume contains a series of twelve Appendices on various topics, among which we note one on the Distribution of Magnetic Dip and Intensity for January, 1890, by C. A. Schott (second edition, with three charts); another by the same author discusses the telegraphic longitude net of the United States, and its connection with that of Europe from 1866 to 1896. Another contains an account of the Magnetic Observations made in connection with the Greenland Expedition of 1896, under the charge of Professor A. E. Burbon, given by G. R. Putnam. Two highly valuable papers by Rollin A. Harris contain a Manual of Tides in two parts,—the first dealing with the history of the subject, the second with tidal observations, equilibrium theory, and harmonic analyses. The fullness of these discussions and the large number of illustrations make this memoir particularly serviceable.

5. *A Catalogue of 2,030 Stars for the epoch 1895, with an Appendix giving the derivation of proper motion for 971 Stars*; by JERMAIN G. PORTER, Director. Publications of the Cincinnati Observatory, No. 114, pp. 114, 4to. Cincinnati, 1898.—This important catalogue containing a second series of five-year observations, with Cincinnati meridian circle by the Director of the Observatory, J. G. Porter, has recently been issued.

6. *Stars and Telescopes. A Hand-book of Popular Astronomy*; by DAVID P. TODD, Director of the Amherst Observatory; pp. 419, with 244 illustrations, including 82 portraits. Boston, 1899. (Little, Brown & Co.) This book is founded on Lynn's Celestial Motions with copious additions by Dr. Todd, especially in the matter of illustrations. In so long a list there are naturally some to be found which could well enough be spared, as drawings of

the supposed markings of Mercury and Venus, and photographs of such mechanisms as the bolometer in a water-jacket and the 40-foot horizontal photo-heliograph in its shed—the view being taken from outside the shed.

Such superfluities do not detract from the value of the book, which is crowded with varied information most attractively presented.

W. B.

7. *Elements of Practical Astronomy*; by W. W. CAMPBELL, Lick Observatory; pp. 264. New York, 1868. (Macmillan & Co.) Based on lectures delivered at Michigan University. A very clear and scientific presentation of as much of the subject as is possible or desirable in training students upon the fundamental principles of telescopic measurements.

W. B.

8. *An Introduction to the Mathematical Theory of Attraction*; by FRANCIS A. TARLETON, Professor of Natural Philosophy in the University of Dublin; pp. 290. New York, 1899. (Longmans, Green & Co.) The theory of attraction, which had its origin in physical astronomy, now finds its more difficult and important uses in electricity and magnetism. As the author points out in his preface, the theory of fluid motion, investigated with such far-reaching results by Helmholtz, Thomson and Stokes, has its leading problems mathematically the same as problems in the theory of attraction. The present text-book gives adequate treatment of the theory in its applications to these lines of research.

W. B.

9. *Les Variations de Longueur des Glaciers dans les Régions Arctiques et Boréales*; by CHARLES RABOT.—In the number of this Journal for November, 1897, an abstract was given of the first part of a memoir on the above subject, published under the auspices of the Commission Internationale des Glaciers. The opening portion of the second part is now published in the number of the *Bibliothèque Universelle* for April 15th. It is chiefly occupied by a discussion of the glaciers of Spitzbergen as observed by various explorers, and gives many interesting facts in regard to this remote region.

10. *The Odonata of Ohio*; by DAVID S. KELLICOTT, Ph.D. pp. 116. Columbus, 1899. Ohio State University. Contributions from the Department of Zoology and Entomology. No. 1.—This valuable paper by the late Professor Kellicott (died April 13, 1898) has recently been issued. It has been edited by Mr. J. S. Hine, who has completed the parts of the manuscript left unfinished; he has also added a sketch of the author's life and a bibliography. The drawings have been made by Mr. W. E. Kellicott.

11. *Electricity in Town and Country Houses*; by PERCY E. SCRUTTON. Second edition, pp. 148. Westminster, 1898. (Archibald Constable & Co.)—This little volume, of which a second edition is now issued, gives an account of the methods employed in installing electricity in houses, with numerous practical illustrations. Besides the application of electricity to lighting, it also discusses briefly some of the various other uses, as a motor, etc., to which it is adapted.

RARE COLORS IN LABRADORITE.



The place of honor this month must be given to Labradorite, for though we have for some time past been advertising fine polished specimens, it is only very recently that we have been successful in finding in our large stock of rough material pieces showing a great variety of the rarer colors. Never before have there been offered so many specimens showing such an assortment of rich colors. One specimen will sometimes exhibit as many as six distinct colors—deep sky blue, light yellowish green, bright yellow, copper red, lavender and maroon—besides many intermediate shades produced by the blending of colors. In addition to the great sheets

and parallel bands of bright colors and the charming irregular blotches of mixed colors, these specimens show good sunstone effects and under a lens the included crystals, both tabular and acicular, are seen to be singularly well developed. Of course there are but very few specimens which combine in one piece all of the above merits; many collectors who see our stock select quite a suite of different specimens. Prices are remarkably cheap—about 10c. to 12c. per square inch.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VIII.—*Rotatory Polarization of Light in Media Sub-
jected to Torsion*; by ARTHUR W. EWELL.

It is stated in Verdet's *Leçons d'Optique Physique** that F. E. Neumann demonstrated mathematically that the plane of polarization of a linear polarized ray, propagated parallel to the axis of a twisted cylinder, is rotated proportionally to the length of the cylinder and the angle of torsion. Verdet remarks that although this result is probably correct, experimental verification is very difficult and had been sought in vain by Neumann and Drion. In the bibliography at the close of the chapter in which these statements occur, three references are given for Neumann's paper. One† relates to the original memoir, the other two to abstracts containing nothing additional.

In this memoir, from the strains when the torsion is small (and when consequently the cross sections remain sensibly plane), Neumann obtains an equation which gives a rotation of the axes of double refraction proportional to the length of the cylinder and in the same direction as the twist but independent of the magnitude of the twist, for rays at an angle with the axis and whose plane of incidence does not include the axis. If the plane of incidence includes the axis or if the ray is parallel to the axis, his equation gives no rotation of the axes of double refraction. Neumann does not state clearly whether he considers that a rotation of the axes of double refraction implies a rotation of the plane of polarization. A careful search failed to bring to light any memoir by Drion on this subject or any other memoir by Neumann.

* Vol. ii, p. 389.

† Abhand. d. königl. Akad. d. Wissen. zu Berlin, 1841, Part II.

I have found but one other memoir directly on this subject. In a paper on torsion Wertheim* describes the optical characteristics of twisted glass cylinders. Glass rods, about 30^{cm} long and 2^{cm} square were annealed until they showed only a faint cross when viewed between crossed Nicols. A double refracting plate giving the sensitive tint was placed between the polarizer and the end of the glass bar. If the analyzer was set at right angles to the polarizer, of the four quadrants into which the dark cross divided the cross section of the prism, two diagonally opposite were green and the other two yellow. If the prism was twisted, the cross left the center, which became yellow if the twist was to the right and green if to the left. However, almost identical results were obtained when the bar was simply rotated to the right or left without twist, whence Wertheim concluded that torsion simply produced double refraction, positive or negative, according to the direction of the twist. Wertheim was much disappointed in his experiments and considered that they decided nothing about the properties of perfectly homogeneous bodies subjected to torsion and that they neither verified nor disproved Neumann's mathematical results.

An interesting parallelism with the action of light in a twisted medium is Bose's† experiment in which he found rotation of the plane of polarization of electro-magnetic waves, traversing a twisted cylinder of jute fibres parallel to the axis. If the twist of the bundle of jute fibres was reversed the plane of polarization was rotated in the opposite direction, but Bose does not state whether the rotation of the plane of polarization was in the same direction as the twist or in the opposite direction. The analogy to light in a twisted medium must not be carried too far on account of the great difference in wave length of the disturbances considered and in the character of the media.

I first studied the effect of torsion on the optical properties of a rectangular glass bar made by Duboscq of Paris, 15^{cm} by 12^{mm} by 7^{mm}. The ends of the bar were placed in thin wooden cylinders with rectangular apertures slightly larger than the bar. These cylinders were grasped by iron clamps attached to long levers by which the torsion was applied. The clamps could grasp the cylinders in any position and thus the bar could be studied in different azimuths. This bar showed no dark cross when placed between crossed analyzer and polarizer, but was dark along the edges. The bar was tested in both the Laurent and Scheibler polarimeters, and although the phenomena were not as distinct as was desirable, and varied in

* *Ann. de chim. et de phys.*, iii, 1. 1857.

† *Proceedings of the Royal Society*, vol. lxiii, 1898.

amount in different azimuths, there seemed to be an unquestionable rotation of the plane of polarization in the opposite direction to the twist, for rays parallel or nearly parallel to the axis of torsion. Before any careful quantitative measurements had been made the bar became suddenly very doubly-refracting, so that on twisting, the only optical change was a clearing up of the center for all azimuths, suggesting the phenomena observed by Wertheim. Soon after it broke. As this bar originally showed no dark cross, more promising results could have been expected than Wertheim obtained with his glass bars and the observations were certainly very suggestive of rotatory polarization, if not decisive.

Four circular glass cylinders, 4 to 6^{cm} long and 7 to 8^{mm} diameter, were examined between crossed polarizer and analyzer and all showed the dark cross and rings. One even showed the double set of rings and dark hyperbolæ of biaxial crystalline plates. The best of these cylinders was heated twenty-four hours in a furnace and carefully cooled. Although one end had been partially fused, the cylinder still showed a cross, but fortunately too faint to seriously disturb observations. Thin wooden cylinders were cemented to the ends and could be grasped in any position by clamps attached to long levers. The torsion was applied by weights hung on these levers 18^{cm} from the axis of the glass cylinder. Observations were made in the Scheibler saccharimeter for each twisting moment at azimuth intervals of 45°. In each azimuth five readings were taken.

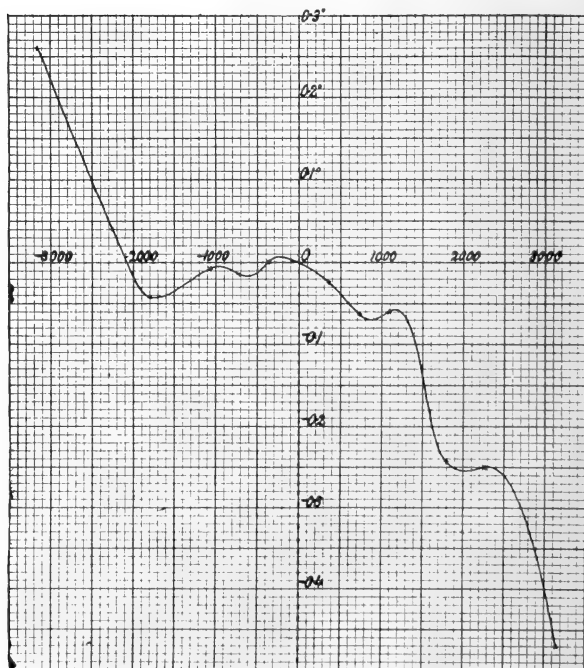
In most of my experiments considerable double refraction appeared on twisting. This would increase in some azimuths and decrease in others the effect of any rotatory polarization which might be present, so that there resulted some irregularity in the observations in different azimuths. Since there is nothing in a double refracting substance to distinguish clockwise and counter-clockwise rotation, if the average of the observations in many different azimuths indicates a distinct rotation of the plane of polarization, the medium must possess rotatory polarization.

In Table I are tabulated the observations with this glass cylinder. The first column gives the number of the experiment, the second the length of the cylinder where the twist could take place, that is, the distance between the wooden cylinders cemented to the ends. After the tenth experiment the cylinder was fractured near one end and when repolished was about 1^{cm} shorter. The twisting moment per centimeter of length is given in the third column in gram-centimeters. The fourth column gives the rotation of the plane of polarization per centimeter of length, after applying the index error of the instrument and reducing the results to angular measure.

TABLE I.

I.	II.	III.	IV.
1	5	0	0°·001
2	"	360	—·022
3	"	720	—·062
4	"	1080	—·060
5	"	1800	—·242
6	"	0	—·006
7	"	—360	·002
8	"	—720	—·014
9	"	—1080	—·006
10	"	—1800	—·042
11	4	2250	—·25
12	"	0	—·12
13	"	—2250	·04
14	"	—3150	·26
15	"	0	·10
16	"	3150	—·47
17	"	0	—·01
18	"	4500	—1·31

Fig. 1.



ANNEALED CIRCULAR GLASS ROD.

Abscissas represent twisting moment per centimeter of length.
 Ordinates represent rotation of the plane of polarization per centimeter of length.

Numbers without the negative sign are always positive. The positive direction of twist and rotation is taken throughout this paper as the direction which appears counter-clockwise to one looking in the direction of propagation of the ray of light.

TABLE II.
Experiment 14.

Twisting Moment per Centimeter = - 3150.						
Azimuth.						Mean.
0	4.5	3.7	3.6	4.7	4.2	4.14
$\frac{\pi}{4}$	.7	1.8	3.	2.6	2.2	2.06
$\frac{\pi}{2}$	2.6	2.2	1.2	.7	.8	1.50
$\frac{3\pi}{4}$	7.2	8.0	7.6	8.2	8.7	7.94
π	-1.7	1.	-.7	-1.4	.3	-.48
$\frac{5\pi}{4}$	8.	8.6	8.7	8.7	8.8	8.56
$\frac{3\pi}{2}$	2.2	1.6	1.7	1.9	1.7	1.82
$\frac{7\pi}{4}$	-3.9	-4.8	-4.4	-3.6	-5.	-4.34

Mean = 2.65

Experiment 16.

Twisting Moment per Centimeter = 3150.						
Azimuth.						Mean.
0	.7	.8	1.1	-.1	1.	.74
$\frac{\pi}{4}$	-6.1	-5.1	-4.1	-4.7	-2.9	-4.58
$\frac{\pi}{2}$	-11.8	-10.4	-11.2	-10.8	-9.8	-10.80
$\frac{3\pi}{4}$	-11.7	-11.7	-11.3	-10.4	-9.8	-10.98
π	-.2	.8	-.9	-1.8	-2.3	-.88
$\frac{5\pi}{4}$	-9.6	-8.7	-8.	-7.	-5.3	-7.92
$\frac{3\pi}{2}$	-11.	-10.3	-8.8	-8.6	-7.6	-9.26
$\frac{7\pi}{4}$	-.8	-3.2	-2.1	-2.4	-1.8	-2.06

Mean = -5.72

These results, excepting those of the last experiment, are given graphically in Fig. 1. The results of the last experiment are uncertain since the cylinder broke after readings had

been made in only two azimuths. The actual twist of the rod was always very small, not exceeding two degrees. The results indicate a rotation in the opposite direction to the twist which becomes very pronounced when the twist is large.

To illustrate these observations, the readings in experiments 14 and 16 are given in detail in Table II. The first column gives the azimuth, that is, the angle between the initial plane of polarization and an arbitrary radius of the glass cylinder; the last column the mean of the preceding five readings in units of the instrumental scale. The irregularity in the readings for a constant azimuth is due to the opacity and lack of homogeneity of the cylinder, which made the setting of the compensator somewhat rough, and the variation in different azimuths is due to double refraction. Although there are these large variations I think the final means have a qualitative value. The diameter of this glass cylinder was 7.55^{mm}.

Glass is an unsatisfactory material for these experiments since it breaks easily and usually shows double refraction, so that observations are difficult. Agar agar, gum sandarach, gum Arabic, Burgundy pitch, borax glass and gelatine were carefully tried, but gelatine alone was found satisfactory.

Square glass plates were cemented to the ends of moderately heavy but soft rubber tubes a few centimeters long and 12^{mm} external diameter. Gelatine was reduced to a jelly by adding a suitable quantity of water, with gentle heat, and poured into these tubes through a slit in the side and allowed to cool. One of these square glass caps was placed in a square aperture at one end of a rigid frame. Over the other glass plate was slipped a circular wooden disk with an opening in the center slightly larger than the glass cap. The jelly tubes were twisted by turning this wooden disk in the frame. When the proper torsion had been secured the disk was clamped and the position of the analyzer read for sixteen different azimuths of the frame relative to the initial plane of polarization. The edge of the disk was graduated and enabled one to determine quite accurately the angle of torsion. The jelly was examined with a polarimeter, the polarizer of which was a reflecting surface of black glass and the analyzer a Nicol mounted on a graduated circle. A biquartz giving the sensitive tint was placed above the polarizing surface, and the substance to be examined between the biquartz and the Nicol. The jelly must be supported in flexible tubes of considerable stiffness. Independent cylinders of jelly were tried, and jelly in thin rubber tubes, but the weight of the jelly and its freedom of motion produced such double refraction that no observations were possible. The independent cylinders of jelly cracked under very slight torsion. Thin paper tubes were tried but found unsatisfactory.

In Table III are tabulated all the observations with jelly tubes. Some tubes were found so double refracting or opaque that determinations were impossible, but the observations are recorded for every experiment where readings could be made. The first column gives the chronological number of the experiment, the second the number of the jelly tube, the third the length of the tube, the fourth the twist per centimeter of length. The fifth column gives the rotation of the plane of polarization per centimeter of length. The readings in brackets for the jelly in its initial condition, before any twist, give the natural negative rotation of the gelatine, if it is pure, or the resultant positive rotation if sugar has been added. This initial rotation has been subtracted from all the readings without brackets so that the unbracketed numbers give the rotation produced by the twist. Each number of the fifth column is the mean of readings in sixteen azimuths.

TABLE III.

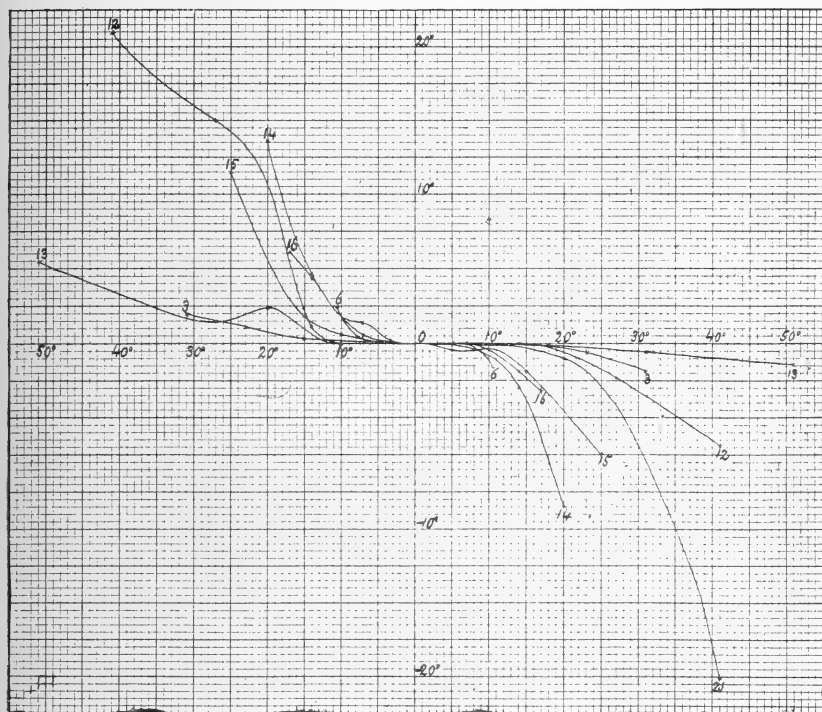
I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
1	1	5.5	15	(0°.63)	38	7	1.55	0	(-1°.86)
2	"	"	0	(.4)	39	"	"	27	-1.7
3	"	"	-15	(.72)	40	"	"	-27	16.7
4	"	"	0	(.65)	41	8	2.07	0	(-1.8)
5	"	"	0	(.83)	42	"	"	20	-.96
6	"	"	15	(1.15)	43	"	"	-20	.1
7	2	"	23	(-3.3)	44	9	3.1	0	(-1.6)
8	"	"	-23	(3.8)	45	"	"	14	-5.1
9	3	"	-18	(2.0)	46	"	"	-14	.06
10	"	"	0	(1.7)	47	10	4.13	0	(-1.3)
11	"	"	18	(.88)	48	"	"	10	2.5
12	"	"	-18	(.83)	49	"	"	-10	5.1
13	"	"	0	(.5)	50	11	6.2	0	(-1.9)
14	"	"	18	(-27)	51	"	"	6	3.7
15	4	"	7	(1.15)	52	"	"	-6	1.8
16	"	"	0	(1.08)	53	12	1.55	0	(-1.02)
17	"	"	-9	(1.06)	54	"	"	14	-.03
18	3	"	0	(.32)	55	"	"	-14	1.28
19	"	"	-7.6	.13	56	"	"	-27	15
20	"	"	-15	.22	57	"	"	27	-2.3
21	"	"	-23	1.1	58	"	"	41	-6.9
22	"	"	0	.14	59	"	"	-41	21
23	"	"	7.6	-.01	60	"	"	-41	17.6
24	"	"	15	-.01	61	13	2.07	0	(-.87)
25	"	"	23	-.65	62	"	"	10	-.12
26	"	"	31	-1.84	63	"	"	-10	-.05
27	"	"	-31	1.98	64	"	"	-20	2.04
28	"	"	0	.2	65	"	"	20	-.18
29	"	"	0	.02	66	"	"	31	-.54
30	5	6	0	(.56)	67	"	"	-31	1.81
31	"	"	7.6	-.5	68	"	"	-51	5.49
32	6	4	0	(-1.2)	69	"	"	51	-1.47
33	"	"	5.2	.1	70	14	3.1	0	(-1.18)
34	"	"	10.5	-1.7	71	"	"	7	-.23
35	"	"	0	-.12	72	"	"	-7	.56
36	"	"	-5.2	.01	73	"	"	-14	4.67
37	"	"	-10.5	2.4	74	"	"	14	-2.98

I	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
75	14	3.1	20	-10°9	102	16	6.2	-14	4°38
76	"	"	-20	13.7	103	"	"	14	-1.97
77	"	"	-20	12.8	104	"	"	17	-3.17
78	15	4.13	0	(-96)	105	"	"	-17	6.06
79	"	"	5	-45	106	17	2.07	0	(-1.7)
80	"	"	-5	18	107	"	"	-20	1.2
81	"	"	-10	73	108	"	"	20	-1.4
82	"	"	10	-36	109	"	"	51	-3.9
83	"	"	15	-1.94	110	"	"	0	.3
84	"	"	0	.01	111	18	"	0	(-4)
85	"	"	-15	1.8	112	"	"	+	.2
86	"	"	0	-25	113	"	"	0	.24
87	"	"	25	-7.75	114	19	3.1	20	(-1.8)
88	"	"	0	-53	115	"	"	-20	(1.7)
89	"	"	-25	11.5	116	"	"	0	(.34)
90	"	"	-25	11.2	117	20	2.07	0	(-78)
91	"	"	0	-43	118	"	"	20	-4.37
92	"	"	25	-10.8	119	"	"	-20	1.15
93	"	"	25	-10.1	120	21	"	0	(-1.36)
94	"	"	0	-77	121	"	"	20	-9.8
95	16	6.2	0	(-1.06)	122	"	"	41	-20.6
96	"	"	3.4	-02	123	22	"	0	(-1.6)
97	"	"	-3.4	23	124	"	"	20	-9.79
98	"	"	-7	1.46	125	23	3.1	0	(-71)
99	"	"	7	-01	126	"	"	21	-5.63
100	"	"	10	-41	127	"	"	21	-4.99
101	"	"	-10	1.78	128	"	"	0	-0.03

Tubes 1, 2, 3, and 5 were filled with a commercial prepared calves-foot jelly, flavored and sweetened. The jelly in tube 1 was too liquid, and the changes in the position of the analyzer are due to temperature changes and other disturbances. A small bubble of air was present in tube 2. The rubber tube of experiment 5 was 3^{cm} in diameter. It gave way after the first twist. Tubes 4, 6-16, 18-23, contained a jelly made from specially refined calves-foot gelatine. The jelly did not cling to the rubber tube or glass plates of tube 4. Tube 6 had a ring of blotting paper around the inside of each end to secure better adhesion. The observations of experiments 37-46 were somewhat uncertain on account of double refraction. The readings with tubes 10 and 11 are unreliable. In successive azimuths the position of the analyzer might change from +50° to -50° owing to great double refraction. Tubes 6-11, 20-23, were filled with very stiff jelly. In tube 18 the jelly was so liquid that it did not cling to the rubber walls or glass and consequently no careful reading of the torsion was made. Tube 17 contained very stiff French fish gelatine. After the experiments with this tube it was found that the polarimeter had been disturbed and that the analyzer and polarizer were parallel when the analyzer was at 11°7. This probably occurred after the zero reading and this is assumed in the fifth column, but on account of this uncertainty this tube does not appear in the plot given later. Tubes 2, 3, 5-9, 12-17, 19-23 show clearly

rotatory polarization in the opposite direction to the twist. The observations with tubes 3, 5, 6 (except the last experiment), 12-16, 19-23, are entitled to the greater confidence. As is remarked above, there is some uncertainty about the readings with tubes 2, 7-9, 17 and the last observations with 6. Tubes 1, 4, 10, 11, 18 do not show rotatory polarization in the oppo-

Fig. 2.



CALVES-FOOT JELLY IN RUBBER TUBES

Abscissas represent twist per centimeter of length.

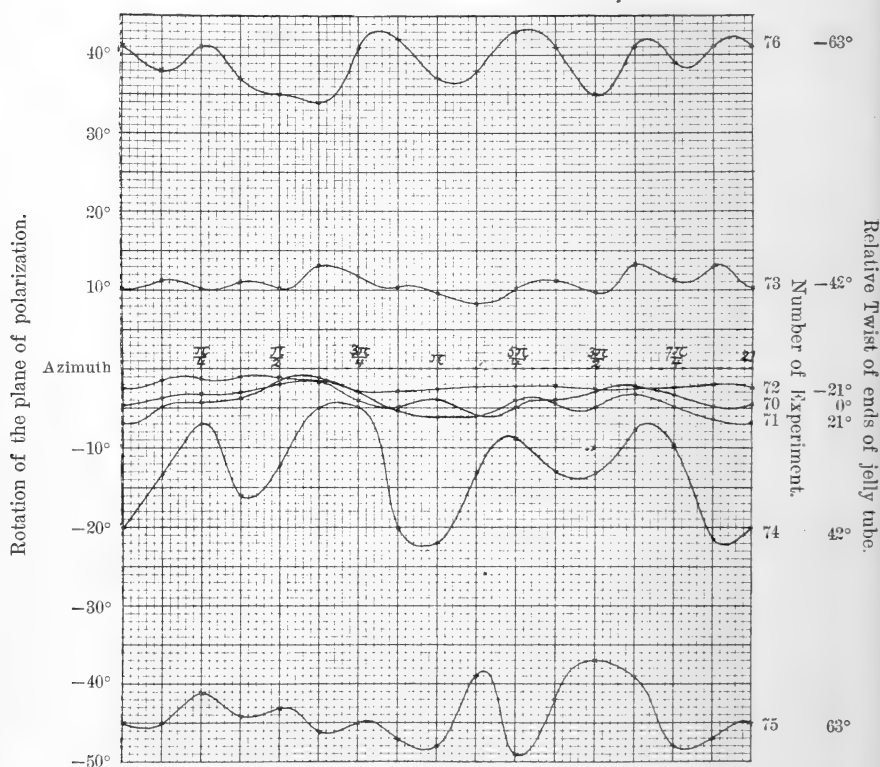
Ordinates represent rotation of the plane of polarization per centimeter of length.

Numbers signify number of jelly tube.

site direction to the twist, but these observations were marked at the time they were made as very uncertain. The observations with the tubes for which the results have no uncertainty, and with which readings were made with more than one positive or negative twist, are represented graphically in fig. 2. It was interesting to notice that the jelly behaved as an elastic solid and did not flow with time as a semi-fluid. The rotation only slightly decreased when a severe twist was continued for hours, and when the twist was removed it nearly returned to its

original natural rotation. Experiments 28, 29, 35, 88, 91, 94, 128 show a small residual rotation after a large twist, but experiments 84 and 86 do not. Observation 60 was made 15 minutes after observation 59; 77, $2\frac{3}{4}$ hours after 76; 90, $2\frac{3}{4}$ hours after 89; 93, 48 hours after 92; 127, $2\frac{3}{4}$ hours after 126; the torsion having been kept constant during these intervals. These show a slight decrease in the rotation if the twist is continued for some time.

Fig. 3.



EXPERIMENTS WITH JELLY TUBE NO. 14.

TABLE IV.
Azimuths.

Twist.	Number of Experiment.	0	$\frac{\pi}{8}$	$\frac{\pi}{4}$	$\frac{3\pi}{8}$	$\frac{\pi}{2}$	$\frac{5\pi}{8}$	$\frac{3\pi}{4}$	$\frac{7\pi}{8}$	π	$\frac{9\pi}{8}$	$\frac{5\pi}{4}$	$\frac{11\pi}{8}$	$\frac{3\pi}{2}$	$\frac{13\pi}{8}$	$\frac{7\pi}{4}$	$\frac{15\pi}{8}$	Mean
			8	4	8	2	8	4	8		8	4	8	2	8	4	8	
0°	70	-4.6	3.6	3.3	3.	1.9	1.8	4.1	4.8	3.9	5.9	4.8	3.9	3.	2.2	3.3	4.7	-3°·7
-21	71	-6.8	4.7	4.3	3.6	1.3	1.1	2.9	5.2	6.1	6.	4.	4.6	4.9	3.2	4.9	6.3	-4.4
-42	72	-2.4	1.4	1.3	1.	1.2	1.6	2.8	2.8	2.6	2.3	2.3	2.3	1.7	1.4	2.2	1.9	-1.95
-42	73	10.2	11.3	10.3	11.	10.2	13.1	11.8	10.3	9.7	8.4	16.1	11.2	9.7	13.4	11.2	13.2	10.9
42	74	-20	13.2	6.9	16	12.2	4.9	4.9	20	21.8	13.1	8.7	13.	13.1	7.6	9.9	21.4	-13.
63	75	-45	45	41	44	43	46	45	47	48	39	49	42	37	39	48	47	-37.8
-63	76	41	38	41	37	35	34	41	42	37	38	43	41	35	41	39	41	39.

To illustrate the character of these observations the readings with tube 14 are given in detail in Table IV and graphically in fig. 3. The abscissas are azimuths, that is, the angle between the initial plane of polarization and an arbitrary radius of the jelly cylinder and the ordinates are rotations of the plane of polarization. The variation in different azimuths with these jelly tubes is very much less than with the glass cylinder.

The effect of torsion in directions perpendicular to the axis was studied in the glass bar made by Duboseq and in a jelly tube with glass windows on the sides. No effect was apparent if the glass bar was exactly perpendicular to the ray of light and with the jelly tube the double refraction was too great for satisfactory observations.

These experiments demonstrate that torsion produces rotatory polarization in the opposite direction to the twist. The curves of fig. 2 indicate that the rotation of the plane of polarization is a function of the twist of degree higher than the first.

It is difficult to find any satisfactory explanation for these phenomena. Crystalline plates helically arranged rotate the plane of polarization, but these phenomena do not seem analogous. In the jelly tubes there could not have been originally any uniform mechanical difference of structure in directions at right angles to the axis of the tube and no such difference could be produced by the torsion in the case of glass. Even if each cross section was analogous to a crystalline plate the helical change of position of the axes would be continuous and not by steps, as is required in Mallard's theory of this rotatory polarization.* Nor can the phenomena be explained on the basis of a structure of helical fibres, for we cannot imagine jelly possessing a fibrous structure, and if we could the twisted fibers would be straight and not helical in distances comparable with the wave-length of light.

Excessively large twists were used in the experiments with jelly. Wertheim demonstrated experimentally in the memoir already referred to, that under large torsion a cylinder is shortened, the contraction being proportional to the distance from the axis. This longitudinal pressure with the torsion stresses would give a component stress in normal sections, but it would seem as if the conditions would be the same for either clockwise or counter-clockwise circular vibrations in these normal sections.

This investigation substantiated the statements of Verdet and Wertheim that the difficulties encountered in the choice of a proper material for experiment are very great. In jelly supported in rubber tubes a satisfactory combination was found,

* *Ann. des Mines*, VII, xix, 1891.

and the observations with jelly, corroborated in the glass, demonstrate that torsion produces rotatory polarization, the rotation of the plane of polarization being opposite to the twist and a function of the twist of degree higher than the first.

In conclusion, I wish to express my thanks to Prof. Wright, who suggested the subject and the general method of the work, and who afforded me all possible facilities for conducting this investigation.

Sloane Physical Laboratory,
Yale University, June 22, 1899.

ART. IX.—*Lichenaria typa* W. & S.; by F. W. SARDESON.

THE purpose of this article is to redescribe an important Tabulate coral from the Ordovician fauna of Minnesota, which has been wrongly referred. It is one of the oldest known Tabulata and its remarkably simple structure may be primitive to that of many others. It should therefore be given consideration whenever the question of origin and affinities of such Tabulata as *Heliolites*, *Favosites*, *Syringopora*, *et al.*, is discussed,—a question upon which paleontologists seem to be not of one opinion. *Lichenaria* presents some special evidence touching the origin of mural pores as seen in many Tabulata, and some remarks on that subject will therefore be added to the description.

Lichenaria typa W. & S., with *Protaræa vetusta* H. and *Aulopora trentonensis* W. & S., occurs in the lower part of the Galena (Trenton) stage, i. e. at about the exact horizon of the Black River formation of New York. Its occurrence is therefore a little earlier than that of *Houghtonia* (*Columnopora*), *Heliolites* and other Ordovician Tabulata excepting some Monticuliporoidea, although it may be considered as essentially their contemporary. Further, *Lichenaria* approaches in structure nearest to *Columnopora* Nicholson as interpreted by me formerly,* but it is very different from *Houghtonia* Rominger, which Lindström has recently asserted to be identical with *Columnopora*† (*Calupæcia* Bill). In fact Rominger and also Nicholson having both said that the same were probably congeneric, while the descriptions of their species are very different, a mistake of some kind is evident, and it may be best eliminated by following the authority of Lindström, loc. cit. In that case, my interpretation of Nicholson's *Columnopora* is faulty also. If it were not so, however, *Lichenaria* would be very near if not congeneric with *Columnopora* as interpreted by me and ranged with *Michelinia*. It is therefore of interest to know that a species of nearly the same structure and geologic age as *Columnopora* Sardeson non Nicholson, the existence of which Lindström has inadvertently denied, does nevertheless exist.

Winchell and Schuchert, in describing *Lichenaria*, referred it to the family Astræidæ of the Madreporaria Aporosa, and their description is unfortunate throughout. The fossil may be recognized, however, from the illustrations, and also since part of the type specimens were received from me and

* Tabulaten, Neues Jahrb. Beilageband, x, p. 295 (1896).

† Heliolitidæ, Kongl. Svenska Vetenskaps-Akad. Handlingar, vol. xxxii, p. 75. (1899).

returned with their identification, I can not be mistaken as to the species which they intended to describe. *Lichenaria* should be referred to the Aleyonaria, Tabulata, near *Miche-linia*.

Lichenaria typa Winchell and Schuchert.

L. typa W. and S., Final rep. Geol. Sur. Minn., vol. iii, p. 83, pl. G. figs. 10-13. (1895). *L. minor* Ulrich, op. cit., p. 84, fig. 5.

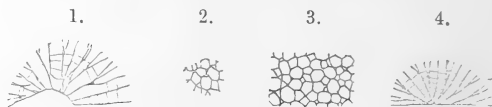


Fig. 1. Vertical section through a corallum, showing mural pores and tabulæ. The latter in part broken away. Fig. 2. Transverse section, showing mural pores, and one cœnenchymal cœcum. Fig. 3. Diagram of the surface of a typical specimen. Fig. 4. Ideal vertical section of specimen growing on plane surface.

Description. Corallum hemispheric or irregular, 20^{mm} or less in diameter, composed of polygonal cells and appearing like young *Favosites*. The corallum was always attached to a shell or a Monticuliporoid and often intergrown with the latter. The cells as a rule rapidly attain the size of 1 to 2^{mm} diameter. The largest cells are seen on largest or oldest colonies but graduation in size to the smallest young cells normally obtains and all colonies therefore appear immature. The cell walls are thin. The calyces are deeper than wide. New cells develop by intermural gemmation at the angles between four or three cells, or at the periphery of the colony intermediate to two older cells. The new cell is at first a round vertical (radial) pore, about 0.2^{mm} in diameter, then as it enlarges it becomes finally polygonal from contact (fig. 3). When the growth is irregular from accidental cause, such as an intergrowing Monticuliporoid, some of the cells may be more or less Auloporoid in their development but there is no Aulopora stage normally. The colony evidently arises from a single polyp which builds a recumbent cell and which early buds off other polyps, resp. cells.

The cell margins are not notched, as now seen, except by the incipient mural pores. These furrows are found especially at the angles between cells, running diagonally between two or branching between three cells, and when they are about to be replaced by one or two incipient cells, small areas result such as Lindström might call cœnenchyma.* The corresponding mural pores are few and not in rows. They are easily found in transparent sections (fig. 1, 2). They are rather large and penetrate the face of the wall less often than the corners.

* Lindström, op. cit., p. 10.

The vertical, intermural canals from which the new cells expand, arise from the mural pores or transverse canals, and hence they open at the bottom into two, rarely into three or one parent cell. But not all mural pores or canals give rise to vertical canals and young cells. In different specimens and different stages of the same, mural pores of both kinds are apparently proportionate to the number of incipient cells, although more numerous than these.

Tabulæ are few and thin, and like the walls they now present a fine crystalline structure only. There is no evidence of "baculi" such as compose the walls and tabulæ* of the well known *Protaræa*. Small direct mural spines, or pseudosepta, are sometimes present but are not distinguishably arranged in continuous rows.

Remarks. The presence of mural pores indicates relationship to such Tabulate corals as *Favosites* and especially to *Michelinia* and *Pleurodictyum*, but the transverse pores are less numerous than in these. The vertical pores or intermural canals are like those of *Pleurodictyum et al.*, and may be interpreted as siphonopores or as cœnenchymal cœca,† if indeed these be not homologous structures. From them budded the new polyp-cells. There are therefore three stages of structural development distinguishable, viz. a pore, i. e. transverse canal, b vertical canal, i. e. siphonopore or cœnenchymal cœcum, and c polyp-cell stage; but since in some cases a complete transverse canal is not developed, and in others such canals exist without accompanying second and third stages, it appears most probable that we have record of two distinct structures, viz., transverse canals and polyps, the young stage of the latter budding often but not always from the former.

It is noteworthy, however, that mural pores are most numerous where most new polyp cells are developing. Beecher's conclusion from study of *Pleurodictyum lenticulare* (Hall), "that primarily, the development of mural pores is identical or homologous with the process of gemination,"‡ is supported, although insufficiently, by this last mentioned character of *Lichenaria*. If it could be assumed in the case of *Lichenaria*, that there were no transverse canals developed other than those which formed the mural pores, then *Lichenaria* would offer a little better evidence than *Pleurodictyum* in support of Beecher's view, since it might be said that non-productive mural pores were developing from productive ones because they are "developed when the period of gemination is

* Full grown, fairly well-preserved specimens of *Protaræa* do have tabulæ, Lindström, op. cit., p. 110, notwithstanding.

† Bourne. Philos. Trans, vol. clxxxvi, B. p. 455 (1895).

‡ Trans. Conn. Acad., vol. viii, p. 212 (1891).

in force," Beecher, op. cit. But it may be an open question whether in *Lichenaria* we see an early stage in the differentiation of transverse canals from stolons or whether it is the incipient stage of mural pore-building by the lodging of pre-existing differentiated canals in the solid wall, as explained by Moseley's theory regarding *Favosites*. Very probably, however, Beecher's theory was suggested less from this kind of evidence, than from a supposed *Aulopora* stage in the development of *Pleurodictyum*, since if *Pleurodictyum* were derived from *Aulopora* then the stolonial structures of the latter would be the origin of those of the former which are also mural pores. But, *Auloporoid* growth in *Lichenaria* is not a normal one, as said, and it may be safely added that there is no *Aulopora* stage in the ontogeny of *Pleurodictyum lenticulare*, the figures 2, 3 and 4, pl. 9, op. cit., being palpably erroneous, and figures 9, 10 and 11 representing not a normal corallum.

Lichenaria appears to prove, therefore, that stolons and transverse canals and the consequent mural pores are older in origin than the oldest known *Tabulata*, and as to the evidence, it does not prove whether canals are older or younger than stolons, although the latter may be the case. The claim that *Aulopora* is ancestral to other *Tabulata* is not supported.

University of Minnesota, Minneapolis,
May 27, 1899.

ART. X. — *Studies in the Cyperaceæ*; by THEO. HOLM.

XI. On the abnormal development of some specimens of *Carex stipata* Muhl., caused by *Livia vernalis* Fitch. (With seven figures in the text drawn from nature by author.)

WHILE the *Cyperaceæ* have several enemies from among the parasitical fungi, they do not seem to be much troubled by parasitical animals. The effects of the attack in the first case prove seldom fatal to the host, since the leaves and leaf-sheaths become merely partially injured, and even if the fungus infests the utriculus of *Carex*, the result of which is generally the destruction of the enclosed caryopsis and seed, the host is, nevertheless, able to propagate itself by means of the rhizome. No outer signs of hypertrophy seem to develop from these diseases, since the tissues attacked by the fungus become rapidly destroyed, while the healthy parts of the leaves are still capable of performing their functions and retain their normal shape and size. It is different, however, when the roots become diseased from this cause, and although such cases seem to be exceedingly rare, we observed a few in *Cyperus flavescens* L., the roots of which were infested with *Schinzia cypericola* Magnus,* which were growing under perfectly normal conditions along the banks of a stream near Washington, D. C. The diseased roots had become very visibly hypertrophied, having increased considerably in thickness at the ends, thus forming small hand- or finger-shaped tumors. But otherwise we have, so far, never observed any such development of "gall" in *Cyperaceæ*, attacked by fungi. There are, however, some certain kinds of malformations, which have been recorded in a number of species of *Carex*, in which the female inflorescences show ramifications, due to a prolongation of rhacheola, but such cases are not to be considered as caused by parasites; they may, as suggested by Duval-Jouve,† be due to the conditions of the soil. Another case is where the utriculus of *Carex disticha* shows a marked increase in size, but this abnormal condition does not seem to have been proved as being caused by parasites. In *Heleocharis* and *Scirpus* there are several species which are frequently viviparous, evidently without being affected by any kind of actual disease; similar viviparous forms are, also, met with among the *Gramineæ*, where they are not uncommon, e. g., the variety "*vivipara*" of *Poa bulbosa*, *Aira alpina*, *Festuca ovina*, *Anthoxanthum odoratum*, etc.‡

* The fungus was kindly identified by Professor Geo. F. Atkinson.

† Duval-Jouve: Sur la signification morphologique d'une anomalie que présentent les utricules de quelques carex. (Bull. soc. bot. de France, vol. xi, 1864.)

‡ The author: Notes on the flowers of *Anthoxanthum odoratum* L. (Proceed. U. S. National Museum, vol. xv, 1892, p. 399.)



FIG 1. *Carex stipata* Muhl. Diseased specimen, showing two leafy shoots with abnormally developed leaves and the base of a flower-bearing stem, which is not diseased; natural size.

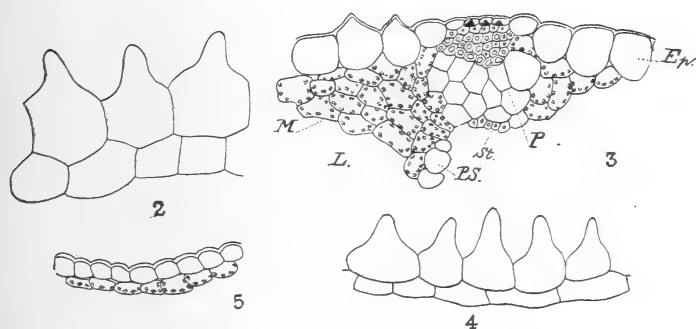
But if we summarize the various causes of diseases and abnormal development as we know these in the *Cyperaceæ*, these do not seem to have been produced by animals, neither as ekto- or endo-parasites. It may, therefore, be of some interest to report an instance where a *Carex*, *C. stipata* Muhl., had become infested by *Livia vernalis* Fitch,* which had caused the foliar organs to develop very abnormally.† The specimens of this *Carex* we found growing under natural conditions, in damp places in woods near Surratsville, Pr. George County, Maryland. They attracted our attention by the unusual size of the leaves, which furthermore were pure white excepting at the tips, which were pale green. The specimens affected in this way were not, however, diseased throughout, as several normally developed shoots, floral and vegetative, were found on the same rhizomes that bore the hypertrophied. The accompanying illustration (fig. 1) shows a part of a diseased specimen with the base of a normal flower-bearing stem and two abnormally developed vegetative shoots. Besides having attained an unusual width and being almost destitute of chlorophyll, these hypertrophied leaves were furthermore flat along their entire length without the usual tubular sheath. The larvæ of the parasite

‡ * The writer is indebted to Dr. Eug. A. Schwartz for the identification of *Livia*.

† Compare Buchenau Fr. Ueber Knollen- und Zwiebel-bildung bei den Juncaceen (Flora, 1891, p. 81).

were located on the upper surface of the leaves, but no punctures were visible, hence the eggs had simply been deposited upon the surface of the leaves, while these were very young and their tissues not quite differentiated.

In comparing the internal structure of a diseased leaf with a healthy one, the most notable difference seems to lie in the epidermis of both faces. This is affected to such an extent that the cells have not only become enlarged, but the outer wall of each individual cell forms a very distinct and projecting, conical papilla. In the healthy leaf the cells of epidermis are rather small on the lower surface with only a few short and wart-like protuberances along the margins of the leaf-blade. On the upper surface the epidermis consists of larger cells, especially above the mesophyll, and wart-like protuberances occur here and there near the ribs and along the margins. Bulliform-cells are developed as a large group above the mid-



Transverse sections of diseased and healthy leaves of *C. stipata*.

FIG. 2. Epidermis and outer layer of mesophyll from the upper surface of diseased leaf.

FIG. 3. Epidermis (Ep.), mesophyll (M.), stereome (St.), colorless parenchyma (P.), and parenchyma-sheath (P.S.) from upper face of healthy leaf.

FIG. 4. Epidermis and outer layer of mesophyll from the lower surface of diseased leaf.

FIG. 5. Epidermis and mesophyll from the lower surface of healthy leaf. $\times 240$.

rib in both the healthy and diseased leaves, but in the latter these cells are very much larger and more numerous. Cells, containing silicious cones, occur as usual outside the hypodermal stereome in the normal leaves, but are almost wanting in those diseased; the same is the case, also, with the stomata, which were noticed only on the lower surface of the green apex, the other part of the blade being destitute of chlorophyll, as stated above. The mechanical tissue, the stereome, is rather thin-walled in the affected leaves, but forms here longer and

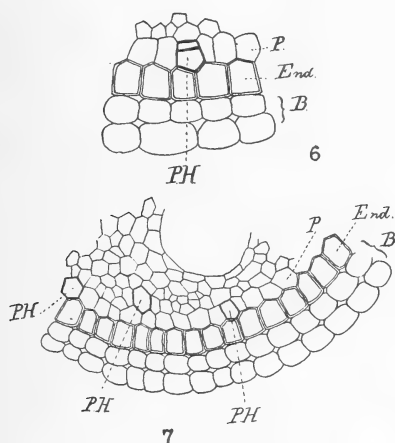
narrower groups than in the healthy ones, when considered in transverse sections. The mesophyll consists of a homogeneous, colorless tissue in the diseased leaves and is traversed by lacunes of considerable width, while this same tissue, in the healthy leaf, is differentiated into a compact, chlorophyll-bearing tissue on the upper face and a more open pneumatical tissue below; lacunes are present, but they are relatively smaller. In considering the mestome bundles, these show the same structure in both leaves, but are more numerous and much broader in those diseased; a parenchyma- and a mestome-sheath are present in both and show the same difference in size, as observed in the other tissues. A study of the silica-skeleton demonstrated the fact, that this matter was almost absent in the infested leaves in contrast to the others.

While our specimens thus possessed both normally and abnormally developed leaves, it seemed as if the rhizome had undergone some modification in its entire length. The bark-parenchyma appeared, however, to be perfectly healthy, representing an outer and inner zone having cells thick-walled and thin-walled respectively and filled with starch; there was, also, an endodermis with the inner walls somewhat thickened. By examining the interior part of the rhizome, the mestome-bundles, these were scattered in the thin-walled, starch-bearing fundamental tissue, and they represented as commonly noticed both collateral and perihadromatic bundles. Very noticeable were the narrow vessels, besides the very weakly developed stereome around each of the mestome-bundles. When compared with a rhizome of a healthy specimen, the difference was very striking and most pronounced by the narrow lumen of the various vessels.

Although the roots showed no signs of any abnormal development, we thought desirable to describe their structure, which exhibited some points that may be of interest for comparative studies of these organs. Their structure is as follows. Inside the epidermis are about four layers of thin walled, but persistent bark-parenchyma, which surrounds the inner bark, the cells of which show the usual tangential collapsing, excepting the two innermost strata. There is, besides, a typical endodermis, of which the cell-walls are slightly thickened all around. The pericambium is very thin-walled and demonstrates the fact (figs. 6 and 7) that it is not interrupted by all the proto-hadrome vessels. Out of thirteen of these vessels two were observed to lie within the pericambium, separated by this from endodermis. In some cases (fig. 6) there was not only one proto-hadrome vessel developed, but two, and contrary to the rule, as it appears, the inner was the smaller. The leptome showed no divergence from that of other roots and

the innermost part of the central-cylinder was occupied by conjunctive tissue with four large vessels.

The approaching or non-approaching of the proto-hadrome to the endodermis has been very broadly discussed in Klinge's classical work, to which we have referred in several of our previously published articles. It appears, according to his observations, that the most common case in the *Cyperaceæ* is that the proto-hadrome borders immediately on the endodermis; this he observed in a number of European species of *Carex*, also in some species of *Eriophorum*, *Scirpus*, *Heleocharis* and of *Cyperus*, the last having previously been studied by Duval-Jouve. However in a few species of *Carex*: *hirta*, *rhynophylla* and *hordeiformis* he observed the same peculiarity as we have described for *C. stipata*, that not all of the proto-hadrome vessels showed this position, but that some were located inside the pericambium. Furthermore, Klinge, Van



FIGS. 6 and 7. Transverse section of root of *Carex stipata*. B = bark-parenchyma; End. = endodermis; PH = proto-hadrome; P = pericambium. $\times 560$ and $\times 400$.

Tieghem and Duval-Jouve discovered, that in certain species of *Cyperus* and *Galilea* from the old world none of the proto-hadrome vessels bordered on endodermis. In the North American *Cyperaceæ*, which we have studied so far, we have constantly observed the proto-hadrome to be in contact with endodermis, the only exception being *Carex Fraseri*, *Fimbristylis castanea*, and this particular case, described above, in *Carex stipata*. This is the more interesting since it seems, also, to be a very rare case in the old world species of *Carex*. It is stated by Van Tieghem as characteristic of *C. brizoides*,

to which Mazel* has later on added: *Carex arenaria*, *C. humilis*, *C. depauperata*, *C. glauca*, *C. alba* and *C. alpestris*. This irregular position of the proto-hadrome in our specimens of *C. stipata* does not, therefore, seem to be in any way the result of disease, since it has, also, been observed in other species with no symptoms of anomaly.

While the disease in *Carex stipata* had not caused the development of a gall or gall-like formation, it is, nevertheless, to be recorded, that there is one analogy to be found in respect to the manner in which the epidermis has been modified in its structure. Küstenmacher† in his interesting work upon galls, describes the various modifications that are observable in the tissues which compose the gall; among these is the so-called nutritive-layer (Nährschicht) which surrounds the animal-embryo, and of which the inner epidermis develops into a mass of papillæ ("papillöse Nährhaare"). As we have stated above, the leaf-surface of our *Carex* showed a corresponding structure with a dense covering of papillæ, but it is, however, far from certain that their function was the same. It seems more probable that the excessive but sickly development of all the parts of the leaf was produced by a kind of irritation, caused by the depositing of the eggs upon the young leaf-surface, without the abnormal structure being of any advantage to the parasite. And although the parasitism was purely superficial from its beginning to end, it, nevertheless, resulted in such important physiological disturbances as: the almost complete non-development of stomata, chlorophyll, lignin and the partial non-absorption of silica.

Brookland, D. C., February, 1899.

* Mazel, Antoine: Etudes d'anatomie comparée sur les organes de végétation dans le genre *Carex*. Thèse. Genève, 1891, p. 88.

† Küstenmacher, Max: Beiträge zur Kenntniss der Gallenbildungen mit Berücksichtigung des Gerbstoffes. (Pringsheim's Jahrb. f. wiss. Botanik, vol. xxvi, Heft I. Berlin, 1894, Inaug. diss.)

ART. XI. — *The Constitution of Tourmaline*; by F. W. CLARKE.

SOME years ago, in an extended paper upon the constitution of the silicates,* I proposed a formula for tourmaline which seemed to satisfy all known conditions. Recently, in the February number of this Journal, Penfield and Foote† have offered still another interpretation of the analyses, and support their views with a considerable weight of argument. The appearance of their paper has led me to rescutinize the evidence more in detail than previously; and the result has been to modify my formulæ in some particulars, while retaining them in their general form.

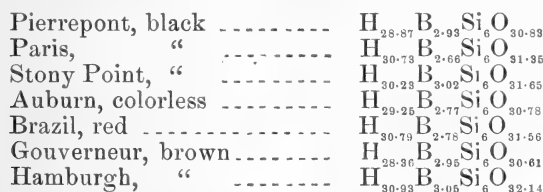
According to Penfield and Foote all tourmaline may be represented as salts of the alumino-borosilicic acid $H_{11}Al_3B_2Si_4O_{21}$, in which two hydroxyls are permanently linked to boron, leaving an available valency or basicity of nine. In my formulæ all tourmalines are derived from the similar acid $H_{14}Al_3B_3Si_6O_{31}$, with all of the hydrogen atoms replaceable by bases. Upon bringing the two acids to the common basis of six silicon atoms, they compare as follows:



Replacing aluminum by hydrogen in order to show the ultimate acids, these expressions become



The small difference between the empirical formulæ is thus made evident, and it hardly amounts to more than the uncertainties in the analyses. In fact, the trustworthy analyses of tourmaline give ratios lying between and beyond both extremes, as the following formulæ, computed from Riggs' data, show: In these expressions fluorine has been assumed equivalent to hydroxyl.



* Bulletin U. S. Geological Survey, No. 125, 1895.

† This Journal, vol. vii, p. 97, 1899.

The two analyses by Penfield and Foote, however, conform sharply to their formula, thus:

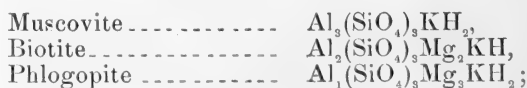


The Gouverneur and Hamburg tourmalines represent the extreme range of variation; a variation which is too large to be safely set aside as due to analytical errors or to impurities in the material analyzed. Some of the formulæ approximate to mine, some to that of Penfield and Foote, and hence it seems probable that neither formula, without some qualification, can safely be taken as final.

In order to be satisfactory, a constitutional formula must fulfil several conditions. First, it must adequately express the composition of the compound in question, covering all of its variations. Secondly, it must be readily applicable to the full discussion of analyses, so that the different isomorphous salts which are commingled in a mineral species can be separately identified and given reasonable expressions. Finally, it should indicate the relations between a species and the other minerals with which it is allied, or into which it commonly alters. A formula can be fully adopted only when all of these conditions are satisfied. The third condition, which relates to function, is equally important with the other two.

With the tourmalines, the micas seem to be most nearly akin. In each group we have to consider comminglings of isomorphous molecules, and when tourmaline alters, a mica is commonly the product of the reaction. In composition, also, the two groups show an apparent parallelism. With the lithia mica, lepidolite, lithia tourmalines occur; with muscovite and biotite, the common iron tourmaline is associated; and the magnesian tourmalines, which show the minimum of alumina in their composition, are similarly allied to phlogopite. This relationship, if it is real, should be suggested in the formulæ assigned to the several species.

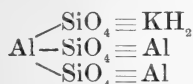
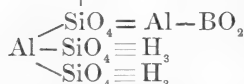
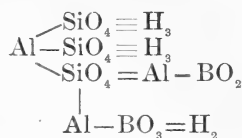
To the commoner micas a simple series of formulæ can be easily given, thus:



and to these types or mixtures of them, most micas are referable. The variations and exceptions have been considered elsewhere, and need not be discussed here.

With these fundamental molecules the corresponding salts of the tourmaline acid $H_{20}B_3Si_6O_{31}$, or $H_{14}Al_5B_3Si_6O_{31}$ are struc-

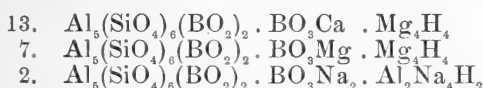
turally correlated. The subjoined formulæ are sufficient to make this point clear; and to render the splitting up of tourmaline, its alteration into mica, somewhat intelligible.

*Muscovite**The Tourmaline Acid.*

In the acid, two hydrogen atoms are united with the orthoboric group, and twelve with the orthosilicate portion of the nucleus. Hence, to avoid repetition of the structural expression, the formula may be condensed into a linear form as follows:



and this is applicable to the discussion of the analyses. For example, Riggs' analysis of the black magnesium tourmaline from Pierrepont, N. Y., corresponds to the following molecular mixture:

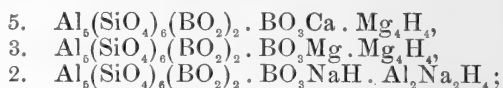


Comparing this with the analysis, and reducing the latter by union of like bases and recalculation to 100 per cent, we have—

	Found.	Reduced.	Calculated.
SiO ₂ -----	35.61	37.19	37.05
B ₂ O ₃ -----	10.15	10.51	10.80
Al ₂ O ₃ -----	25.29	27.10	27.19
Fe ₂ O ₃ -----	.44		
TiO ₂ -----	.55		
CaO -----	3.31	3.45	3.40
FeO -----	8.19		
MgO -----	11.07	16.31	16.28
Na ₂ O -----	1.51	1.72	1.74
K ₂ O -----	.20		
H ₂ O -----	3.34	3.72	3.54
F -----	.27		
	<hr/> 99.93	<hr/> 100.00	<hr/> 100.00

The result is evidently satisfactory. In dealing with titanium I have followed Penfield, regarding it as really Ti_2O_3 and equivalent to alumina. The fluorine is treated as replacing hydroxyl and is, therefore, united with the water. It is possible, however, that fluorine may sometimes replace the group BO_2 , an equivalency which is strongly indicated in the cap-pelenite group of minerals.

The brown tourmaline from Gouverneur, N. Y., as analyzed by Riggs, also reduces to a similar mixture of molecules, and its composition may be written thus:



and the comparison between analysis and theory is as follows:

	Found.	Reduced.	Calculated.
SiO_2 -----	37.39	37.54	37.32
B_2O_3 -----	10.73	10.76	10.88
Al_2O_3 -----	27.79	28.72	28.53
Fe_2O_3 -----	.10		
TiO_2 -----	1.19	14.51	14.52
FeO -----	.64		
MgO -----	14.09		
CaO -----	2.78	2.79	2.90
Na_2O -----	1.72	1.83	1.93
K_2O -----	.16		
H_2O -----	3.83	3.85	3.92
	<hr/> 100.42	<hr/> 100.00	<hr/> 100.00

By consolidating lime with magnesia the expressions for both tourmalines might be simplified; but in other cases this would not be warranted. In some tourmalines calcium seems rather to replace sodium, or else the group NaH ; a probability which will appear later.

In these two tourmalines the theoretical silicon-oxygen ratio Si_6O_{31} is assumed, in accordance with my original formula. We may now consider the cases in which that ratio is exceeded, with more or less approach to the formula proposed by Penfield and Foote. This condition is easily satisfied by regarding one of the component salts of tourmaline as slightly basic; containing the bivalent group $=\text{Al}-\text{O}-\text{H}$ or $=\text{Al}-\text{F}$ as an essential factor. With this assumption, which recognizes the equivalency of hydroxyl and fluorine, the analyses reduce to the general type indicated in the two preceding examples. For instance, the white tourmaline from DeKalb, N. Y., has the following composition:

10. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3(\text{AlOH}) \cdot \text{Mg}_4\text{H}_4$.
 20. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Ca} \cdot \text{Mg}_4\text{H}_4$.
 3. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Na}_2 \cdot \text{Al}_3\text{Na}_3$.

For comparison the analyses by Penfield and Foote and by Riggs are available. In this case the minute quantities of titanium are ignored.

	Found.		Reduced.			Calculated.
	P. & F.	Riggs.	P. & F.	Riggs.	Mean.	
SiO_2 -----	36.72	36.88	36.56	36.81	36.69	36.79
TiO_2 -----	.05	.12				----
B_2O_3 -----	10.81	10.58	10.76	10.56	10.66	10.74
Al_2O_3 -----	29.68	28.87	29.55	28.81	29.18	29.07
FeO -----	.22	.52				
MgO -----	14.92	14.53	14.97	14.79	14.88	14.86
CaO -----	3.49	3.70	3.47	3.69	3.58	3.48
Na_2O -----	1.26	1.39	1.28	1.50	1.39	1.44
K_2O -----	.05	.18				
H_2O -----	2.98	3.56	3.41	3.84	3.62	3.62
F -----	.93	.50				
	101.11	100.83	100.00	100.00	100.00	100.00

The dark brown tourmalines from Orford, N. H., and Monroe, Conn., as analyzed by Riggs, also reduce to similar form, and approximate to the mixture

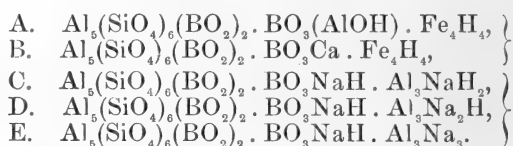
15. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3(\text{AlOH}) \cdot \text{Mg}_4\text{H}_4$,
 6. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Ca} \cdot \text{Mg}_4\text{H}_4$,
 8. $\text{Al}_5(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{NaH} \cdot \text{Al}_3\text{Na}_2\text{H}$,

with the comparison as follows:

	Found.		Reduced.		Calculated.
	Orford.	Monroe.	Orford.	Monroe.	
SiO_2 -----	36.66	36.41	36.96	37.34	36.84
B_2O_3 -----	10.07	9.65	10.16	9.89	10.74
Al_2O_3 -----	32.84	31.27	33.28	33.13	33.11
TiO_2 -----	.23	1.61			
FeO -----	2.50	3.80			
MgO -----	10.35	9.47	11.84	11.88	11.85
CaO -----	1.35	.98	1.36	1.00	1.19
Na_2O -----	2.42	2.68	2.58	2.88	2.62
K_2O -----	.22	.21			
H_2O -----	3.78	3.79	3.82	3.88	3.65
	100.42	99.87	100.00	100.00	100.00

Here the divergence between the composition as found and as calculated is evidently due to the low determinations of boric acid in the analyses. Still, the comparison is close.

Between the magnesium tourmalines and the iron tourmalines the closest analogy exists, and the identity of type is absolute. Taking, except when otherwise specified, the analyses by Riggs, all the iron tourmalines reduce to mixtures of the following isomorphous molecules:



Molecules C, D, and E are evidently identical, except in the varying replacements of sodium by hydrogen. A and B are similarly alike, so that actually only two fundamental compounds are assumed. From the commoner iron tourmalines lime is practically, if not quite absent; and these may be interpreted very nearly as mixtures of A and C, such as A_8C_5 , A_7C_6 , etc. If we take the minute quantities of lime into account, the black tourmalines from Brazil and from Stony Point, N. C., correspond to $\text{A}_{13}\text{B}_2\text{C}_9$; that from Auburn, Me., to $\text{A}_{35}\text{B}_2\text{C}_{27}$; and that from Paris, Me., to $\text{A}_{10}\text{B}_1\text{C}_9$. It will be noticed that the molecule A is in excess of the other two; a condition which fits the analyses, but which is incompatible with the formula proposed by Penfield and Foote. To satisfy the latter the number of A molecules should be exactly equal to B+C, giving the ratio Si_4O_{21} or $\text{Si}_6\text{O}_{31\frac{1}{2}}$. The analyses in question are as follows:

	Brazil.	Stony Point.	Auburn.	Paris.
SiO_2 -----	34.63	35.56	34.99	35.03
B_2O_3 -----	9.63	10.40	9.63	9.02
TiO_2 -----	-----	.55	-----	-----
Al_2O_3 } -----	32.70	33.38	33.96	34.44
Fe_2O_3 } -----	.31	-----	-----	1.13
FeO } -----	13.69	8.49	14.23	12.10
MnO } -----	.12	.04	.06	.08
MgO } -----	2.13	5.44	1.01	1.81
CaO -----	.33	.53	.15	.24
Li_2O } -----	.08	trace	-----	.07
Na_2O } -----	2.11	2.16	2.01	2.03
K_2O } -----	.24	.24	.34	.25
H_2O } -----	3.49	3.63	3.62	3.69
F } -----	.06	-----	-----	-----
	<hr/> 99.52	<hr/> 100.42	<hr/> 100.00	<hr/> 99.89

The reduced analyses and their comparison with the calculated composition is as follows:

	Found. Stony Pt.	Found. Brazil.	Calc. $A_{13}B_3C_9$.	Found. Auburn.	Calc. $A_{35}B_2C_{27}$.	Found. Paris.	Calc. $A_{10}B_1C_9$.
SiO_2 ---	34.10	34.26	34.27	34.75	34.48	34.70	34.62
B_2O_3 ---	9.98	9.54	9.99	9.56	10.06	8.94	10.10
Al_2O_3 ---	32.37	32.54	32.36	33.73	33.28	34.82	33.60
FeO ---	17.33	17.45	17.14	15.99	15.95	15.30	15.23
CaO ---	.52	.33	.45	.15	.17	.25	.27
Na_2O ..	2.22	2.40	2.22	2.23	2.50	2.33	2.67
H_2O ---	3.48	3.48	3.57	3.59	3.56	3.66	3.51
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Here again the agreements between analysis and theory are as close as could be reasonably expected. The same thing is true of the black tourmalines from Haddam, Conn., and Nantic Gulf. Using letters to represent the several molecules, as above, the Haddam mineral is sharply represented by $A_4B_1D_2$, and that from Nantic Gulf by $A_6B_1C_3E_1$. Here is the comparison:

	Haddam.			Nantic Gulf.		
	Found.	Reduced.	Calc.	Found.	Reduced.	Calc.
SiO_2	34.95	33.78	33.67	35.34	33.34	33.60
B_2O_3	9.92	9.60	9.82	10.45	9.86	9.80
TiO_2 .....	.57			.40		
Al_2O_3	31.11	30.74	30.67	30.49	29.01	28.84
Fe_2O_3 .....	.50			---		
FeO	11.87	19.31	19.24	8.22	20.46	20.55
MnO .....	.09			trace		
MgO	4.45			7.76		
CaO .....	.81	.78	.75	2.32	2.19	2.15
Na_2O	2.22	2.30	2.48	1.76	1.74	1.70
K_2O .....	.24			.15		
H_2O	3.62	3.49	3.37	3.60	3.40	3.36
	100.35	100.00	100.00	100.49	100.00	100.00

To the lithia tourmalines, as analyzed by Riggs, a similar set of formulæ apply, although the comparison between fact and theory is not quite so close as in the preceding cases. The red tourmalines from Brazil and from Rumford, Maine, are very nearly represented by the expression



with Li:Na approximately as 5:4. The slight deficiency in the alkalis is made up by the presence of small amounts of calcium, iron and manganese; but the ratio $Al_6:Si_6$ is very

clear. The green tourmalines are all lower in alumina, and range downward towards the iron-end of the series; and like the latter are representable as mixtures of the following molecular types:

- A. $\text{Al}_6(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3(\text{AlOH}) \cdot \text{Fe}_4\text{H}_4$.
 B. $\text{Al}_6(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Ca} \cdot \text{Fe}_4\text{H}_4$.
 C. $\text{Al}_6(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{LiH} \cdot \text{Al}_2\text{Li}_2\text{H}_4$.
 D. $\text{Al}_6(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{NaH} \cdot \text{Al}_3\text{NaH}_2$.
 E. $\text{Al}_6(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{H}_2 \cdot \text{Al}_3\text{NaH}_2$.

Thus the dark, opaque green tourmaline from Rumford, Me., is a molecular mixture corresponding to $\text{A}_6\text{B}_2\text{C}_7\text{D}_{14}\text{E}_6$; the similar mineral from Auburn is $\text{A}_8\text{B}_1\text{C}_8\text{D}_{17}$; the light green from Auburn, $\text{A}_2\text{B}_3\text{C}_{10}\text{D}_8\text{E}_{12}$; and the nearly colorless from Auburn, $\text{A}_1\text{B}_6\text{C}_{20}\text{D}_{10}\text{E}_{35}$. From Brazil, the dark green is $\text{A}_2\text{B}_1\text{C}_6\text{D}_8$, and the light green is $\text{A}_1\text{B}_2\text{C}_9\text{D}_8\text{E}_5$. The complexity of these expressions is only apparent, not real; as a study of the original type formulæ will show. They compare with the *reduced* analyses as follows:

	Rumford.		Auburn, dark.		Auburn, medium.		Auburn, pale.	
	Found.	Calc.	Found.	Calc.	Found.	Calc.	Found.	Calc.
SiO_2 ..	36.68	36.69	36.37	36.45	37.95	37.52	38.25	37.92
B_2O_3 ..	10.26	10.69	9.98	10.63	10.57	10.94	10.30	11.05
Al_2O_3 ..	38.26	37.74	36.89	37.21	38.11	39.02	39.92	40.17
FeO ..	6.78	6.90	7.94	7.72	4.47	4.28	2.75	2.56
CaO ..	.34	.34	.17	.16	.50	.50	.43	.49
Na_2O ..	3.12	3.07	3.19	3.14	2.58	2.58	2.55	2.53
Li_2O ..	.95	.94	1.06	1.07	1.35	1.35	1.34	1.34
H_2O ..	3.61	3.63	4.40	3.62	4.47	3.81	4.46	3.94
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

	Brazil, dark.		Brazil, light.	
	Found.	Calc.	Found.	Calc.
SiO_2	37.24	37.14	37.49	37.64
B_2O_3	9.95	10.83	10.32	10.97
Al_2O_3	38.66	38.07	39.86	39.04
FeO	5.49	5.24	3.74	3.61
CaO} .....	.39	.35	.49	.46
Na_2O	2.90	3.01	2.59	2.76
Li_2O	1.63	1.64	1.71	1.69
H_2O	3.74	3.72	3.80	3.83
	100.00	100.00	100.00	100.00

In these cases the low boric acid of the analyses, and the uncertainties as to the significance of the water determinations,

account for the chief variations between observation and theory. There is another complication also, due to the fact that alternative expressions are possible, between which it is very difficult to decide. In the tourmaline from Haddam Neck, Conn., analyzed by Penfield and Foote, a somewhat different commingling of molecules seems to be necessary, partly on account of the higher proportion of lime in the mineral, and partly on account of the fluorine. This tourmaline, also, admits of various alternatives in formulation; but it agrees well with the molecular mixture

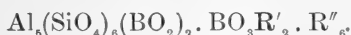
3. $\text{Al}_3(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Ca} \cdot \text{Fe}_4\text{H}_4$,
10. $\text{Al}_3(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3(\text{AlOH}) \cdot \text{Al}_2\text{Li}_2\text{H}_4$,
1. $\text{Al}_3(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{Ca} \cdot \text{Al}_3\text{NaH}_2$,
6. $\text{Al}_3(\text{SiO}_4)_6(\text{BO}_2)_2 \cdot \text{BO}_3\text{NaH} \cdot \text{Al}_3\text{NaH}_2$;

in which Ca is equivalent to a replacement of NaH. This mixture, with the group AlOH proportional to fluorine, gives a good comparison between analysis and theory, thus:

	Found.	Reduced.	Calculated.
SiO_2 -----	36.96	36.75	36.86
B_2O_3 -----	11.00	10.94	10.74
TiO_2 -----	.03		
Al_2O_3 -----	39.56	39.35	39.44
FeO -----	2.14	4.35	4.43
MnO -----	2.00		
MgO -----	.15		
CaO -----	1.28	1.27	1.15
Na_2O -----	2.10	2.09	2.07
Li_2O -----	1.64	1.63	1.54
H_2O -----	3.10	3.62	3.77
F -----	1.13		
	<hr/> 101.09	<hr/> 100.00	<hr/> 100.00

The theoretical amount of fluorine needed to replace hydroxyl in the assumed group, AlOH, is 0.97 per cent. Altogether, the comparison is fairly satisfactory.

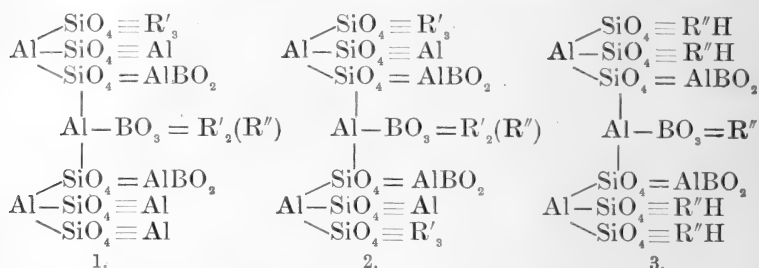
One analysis by Riggs, that of the magnesium tourmaline from Hamburgh, N. J., I have omitted from my discussion. In that tourmaline there are variations which I cannot readily account for, unless by assuming the presence in it of a molecule



Such a molecule, written structurally, exhibits affinities to garnet, rather than to the micas; and I prefer to await further evidence before committing myself to any definite formulation in this instance. As for the analyses published by Jannasch

and Kalb, they fit in well with those of Riggs, and are amenable to the same treatment.

At first glance, some of the formulæ which I have proposed may seem to be complex; but they are all of the same type, and can be reduced to a few general expressions, as follows:



These formulæ cover all of the established variations in the composition of tourmaline, they render the various replacements or isomorphous admixtures intelligible, and they indicate the directions into which the species commonly alters. There is one objection to them, namely, that one of the end products contains no alkali metal, and no alkali free tourmaline is known. The same objection applies to the Penfield-Foote formula, as will be seen by any one who attempts to apply it in the discussion of the iron tourmalines. Under either system of formulation the existence in tourmaline of alkali-free salts must be assumed.

One further possible advantage in the proposed formulæ remains to be pointed out. All of the chemists who of late years have discussed the composition of tourmaline agree in adopting the ratio between silicon and boron of 2 : 1, or $4\text{SiO}_2 : \text{B}_2\text{O}_3$. And yet many of the analyses vary from this ratio to an extent which may not be due to experimental errors. For example, from among Riggs' analyses the following cases show large variations, the boron being too low. I give the silica and boric oxide as determined; the boric oxide as calculated from the silica by the accepted ratio, and the amount of variation between the two.

	SiO ₂	B ₂ O ₃ found.	B ₂ O ₃ calc.	Diff.
Rumford, red	38·07	9·99	11·10	—1·11
Paris, black	35·03	9·02	10·22	—1·20
Monroe, brown	36·41	9·65	10·62	—0·97
Brazil, green	36·91	9·87	10·76	—0·89
Auburn, colorless ...	38·14	10·25	11·12	—0·87

In the analyses by Jannasch and Kalb the following examples are very striking:

	SiO ₂ .	B ₂ O ₃ found.	B ₂ O ₃ calc.	Diff.
Snarum	35·64	9·93	10·40	—1·47
Mursinka	34·88	8·94	10·17	—1·23
Buckworth	35·50	8·34	10·35	—2·01
Brazil	37·05	9·09	10·81	—1·72

It would hardly be wise to dismiss these variations as due to errors, especially when the summation of the analyses is good, and the analysts are known to be trustworthy. Such errors on the part of either Jannasch or Riggs would be almost incredible, and I am, therefore, inclined to believe that the analyses are good, and that we should seek a cause for the variations. In my scheme of formulation the bivalent group of atoms =Al—BO₂ occurs. Replace this in part by the similar groups =Al—OH and =Al—F, and the variations are accounted for. This supposition satisfies the analyses completely, and covers the ground. It is in accord with all the evidence, even though its validity may not be definitely proved. By its application to the discussion of the analyses the divergencies between the calculated composition and the composition as found, can be notably diminished.

But although the formulæ which I have adopted serve to express the composition of all tourmalines, they still leave room for alternatives. Penfield and Foote, as well as myself, assume that tourmaline is a mixed salt containing distinct boric and silicic radicles. Future investigation may prove that it is really derived from a complex boro-silicic acid, as yet unknown; and the same conception may be true of other species, such as axinite, datolite, danburite, cappelinite, etc. A series of boro-silicic acids is theoretically conceivable; and until this question has been considered, the constitution of all the minerals above-mentioned must be regarded as unsettled.

Washington, April 19, 1899.
U. S. Geological Survey.

ART. XII.—*The Determination of Tellurous Acid in presence of Haloid Salts*; by F. A. GOOCH and C. A. PETERS.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIV.]

THE estimation of tellurous acid by oxidation with excess of potassium permanganate (either in acid or alkaline solution), destruction of the higher oxides of manganese or the manganate by standard oxalic acid in presence of sulphuric acid, and titration of the residual oxalic acid by more permanganate, has been shown by Brauner* to be feasible. The tendency of the permanganate to throw off too much oxygen when the oxidation is made in solutions strongly acidified with sulphuric acid (as must be the case if the tellurous oxide is to be held permanently in solution by sulphuric acid) necessitates the application of a considerable correction.† Fortunately, however, as has been shown in a former paper from this laboratory,‡ when the tellurous oxide is dissolved originally in an alkaline hydroxide and the solution made acid only to a limited degree with sulphuric acid either before or after oxidation by the permanganate, no correction appears to be necessary. Thus, when an excess of permanganate is added to the alkaline solution, followed by an excess of oxalic acid and sulphuric acid to an amount not exceeding 5^{cm}³ of the [1 : 1] mixture with water, the titration of the residual oxalic acid by more permanganate (after heating to 80° C.) leads to results which give no indication of over-decomposition of the permanganate; so also, when the process is similarly conducted excepting that before addition of the permanganate the original alkaline solution is acidified with sulphuric acid [1 : 1] to an amount 1^{cm}³ in excess of that necessary to re-dissolve the first precipitate, the results are theoretically accurate, and in close agreement with those obtained by the former procedure.

In the presence of free hydrochloric acid the action of the permanganate upon tellurous acid has been shown by Brauner§ to be irregular and excessive, and the irregularity cannot be corrected (as in the titration of ferrous salts in presence of hydrochloric acid) by the addition of a manganous salt according to the well-known procedure of Kessler|| and Zimmermann.¶ So far as appears, however, there should be nothing to prevent the accurate determination of tellurium in tellurous compounds in the presence of chlorides by the permanganate process providing the first oxidation is made in alkaline solution, and the second oxidation carried out with such precautions

* Jour. Chem. Soc. 1891, p. 238.

† Loc. cit., p. 249.

‡ Gooch and Dauner: this Journal, xlv, 301.

§ Loc. cit., p. 241.

|| Ann. der Phys., cxviii, 48; cxix, 225, 226.

¶ Ann. der Chem., cexiii, 302.

as are necessary to a correct determination of oxalic acid by permanganate in presence of hydrochloric acid; for, the special danger of over-action on the part of the permanganate cannot exist while the solution is alkaline, and has passed when the tellurite has become a tellurate and before the solution is made acid. As to the proper conditions for the titration of oxalic acid by permanganate we have shown recently* that the presence of a manganous salt is necessary and sufficient to secure regularity of action when a considerable amount of hydrochloric acid is in the solution; when the amount is small—so much as would be formed in the decomposition of a gram or two of halogen salt of tellurium—the disturbing effect under ordinary conditions of work is probably inappreciable, but even in such a case it is better to work in the presence of a manganous salt for the reason that the titration of the oxalic acid may then be made at the ordinary atmospheric temperature.

In the following table are gathered the results of experiments made with, and without, the addition of the manganous salt.

TABLE I.

O = 16, Te = 127.5.

Volume at beginning, 150 cm³.

Temperature of titration, 60–80° C.

TeO ₂ taken.	NaCl.	H ₂ SO ₄ 1:1.	MnCl ₂ .4H ₂ O.	TeO ₂ found.	Error.
gram.	gram.	cm ³ .	gram.	gram.	gram.
0.1000	.4	5	----	0.1003	+0.0003
0.1000	.4	5	----	0.1000	0.0000
0.1000	.4	5	----	0.1004	+0.0004
0.1000	1.0	5	----	0.1003	+0.0003
0.0650	1.0	5	----	0.0653	+0.0003

B.

Temperature of titration, 20–26° C.

0.0700	.4	5.7	1.0	0.0705	+0.0005
0.0700	.4	5.7	1.0	0.0698	—0.0002
0.0700	.4	5.7	.5	0.0701	+0.0001
0.1000	.4	5.7	.5	0.1008	+0.0008

The tellurium dioxide, made by the careful ignition of the crystallized basic nitrate obtained by oxidizing tellurium with nitric acid, was dissolved in a small amount of sodium hydroxide, the halogen salt was added to the amount shown, the permanganate standardized against ammonium oxalate was run in until its characteristic color appeared, standard ammonium oxalate was added in excess of the quantity required to reduce the excess of permanganate, manganate, and higher oxides, and

* This Journal.

the solution was heated with enough sulphuric acid [1:1] to neutralize the alkaline hydroxide and have an excess of about 5^{cm}³. In the experiments of Section A the liquid was heated to 60°–80° C. to dissolve the oxides at the final titration begun at that temperature; in those of Section B, manganous chloride (0.5 to 1 gram) was added, so that the reduction of the higher oxides of manganese and the final titration of the excess of oxalic acid might take place at the ordinary temperature of the room.

Plainly the presence of the chloride does not interfere materially in the determination of the tellurium by this process whether the titration is made at a high or low temperature.

It appears, also, upon putting the matter to the test, that fairly good determinations of tellurous acid may be made similarly in the presence of a bromide, provided the titration is made at the atmospheric temperature in the presence of a sufficiency (0.5 gram to 1 gram) of a manganous salt and of an excess of sulphuric acid limited to about 5^{cm}³ or less of the 12.5 per cent mixture. At the higher temperatures bromine is liberated at once from the acid solution by the permanganate. The experimental results are given in Table II.

TABLE II.

O = 16, Te = 127.5.
Volume at beginning, 150^{cm}³.
Temperature of titration, 24°–26° C.

TeO ₂ taken. gram.	NaCl. gram.	KBr. gram.	H ₂ SO ₄ 12.5 % cm ³ .	MnCl ₂ . 4H ₂ O. gram.	TeO ₂ found. gram.	Error. gram.
0.1000	----	0.5	20	1.0	0.1022	+0.0022
0.3000	----	1.5	25	1.0	0.3030	+0.0030
0.0650	----	0.5	1	1.0	0.0661	+0.0011
0.0650	----	0.5	1	1.0	0.0647	–0.0003
0.1000	----	0.5	1	1.0	0.1002	+0.0002
0.3000	----	0.5	5	0.5	0.3010	+0.0010
0.0650	0.5	0.5	1	1.0	0.0661	+0.0011

It is obvious, therefore, that tellurous acid may be determined with a fair degree of accuracy by the permanganate method in the presence of chlorides and bromides, provided the first oxidation is made in alkaline solution and the final titration of the residual oxalic acid is made at ordinary temperatures in the presence of a manganous salt and restricted amounts of free sulphuric acid.

In the presence of an iodide, however, the case is different. Upon acidifying the mixture of iodide and the higher oxygen compounds of manganese, produced in the action of the permanganate upon the solution, iodine is at once set free, and

oxalic acid does not suffice to reconvert it. In the presence of an excess of potassium iodide the higher manganic compounds are completely reduced with rapidity and the iodine liberated is the measure of the excess of permanganate over that required to oxidize the tellurous acid; the difference between the amount of permanganate thus indicated and that originally introduced should determine the amount of the tellurous acid. It is upon this basis that Norris and Fay* have founded their excellent iodometric determination of tellurous acid. This process consists in treating the alkaline solution of tellurous acid with standard permanganate until the meniscus of the liquid shows a deep pink color, then diluting the solution with ice-water, adding potassium iodide and sulphuric acid, and titrating with sodium thiosulphate. The results are excellent.

It is plain that any agent capable of converting the iodine to hydriodic acid without at the same time reducing telluric acid should be capable of measuring the excess of the permanganate, and so the amount of tellurous acid originally present.

We find that the standard arsenite made, as usual, by dissolving 4.95 grams of pure resublimed arsenious oxide to the liter of water containing potassium bicarbonate answers the purpose admirably, and possesses the further advantage of fixing at once the entire standard of the process, the strength of the permanganate (approximately $\frac{n}{10}$) being determined by running a definite volume of its solution into water containing potassium iodide (1 gram) with 2 to 3^{cm} of dilute sulphuric acid and titrating by the standard arsenite the iodine (set free by the action of the excess of permanganate and higher oxides) after neutralization with acid potassium bicarbonate. In this titration of iodine by the arsenite we find it best to dispense with the starch solution usually employed to secure the end reaction. The color of the free iodine itself is sufficiently definite, even at a dilution so much as 300^{cm}, and its disappearance under the action of the arsenite is much sharper than that of the blue starch iodide.

In Table III are recorded results obtained by adding the alkaline solution of tellurous oxide to 100^{cm} of water containing 0.5 gram or 1 gram of potassium iodide, introducing the standardized potassium permanganate until the green color of the manganate appears (about 30^{cm} of the $\frac{n}{10}$ solution for every 0.1 gram of TeO_2), adding a few cubic centimeters of dilute sulphuric acid followed, when the solution has cleared and separated iodine, by an excess of acid potassium carbonate,

* Am. Chem. Jour., xx, 278.

and titrating to the destruction of color with the standard solution of arsenic. It is essential in order that oxygen may not go to waste in the breaking down of the oxides, that more than enough iodide should be present when the solution is acidified to complete the reduction of the manganese oxides, or else, that the arsenious acid should be present in suitable amount before the sulphuric acid is put in. This latter procedure may be used in case, for any reason, it is preferred not to introduce more iodide into the solution than may be present originally: when, for example, a direct determination of the iodine present is to follow.

TABLE III.

O = 16, Te = 127.5.

TeO ₂ taken. grm.	NaCl. grm.	KBr. grm.	KI. grm.	Total volume at end. cm ³ .	NaOH present during oxidation. grm.	TeO ₂ found. grm.	Error. grm.
0.1000	----	----	.5	160	0.1	0.1005	+ .0005
0.1000	----	----	.5	160	0.1	0.1001	+ 0.0001
0.1000	----	----	.5	160	0.1	0.1003	+ 0.0003
0.1000	----	----	1.0	250	0.1	0.1007	+ 0.0007
0.2000	----	----	1.0	250	0.2	0.1997	- 0.0003
0.1000	.5	.5	.5	250	0.1	0.1000	0.0000
0.2100	1.0	1.0	1.0	225	0.2	0.2105	+ 0.0005
0.1000	----	----	.5	160	1.0	0.1011	+ 0.0011
0.2000	----	----	1.0	300	2.0	0.2009	+ 0.0009

These results are reasonably good. Like those of Table I they would be brought practically in the average to the figure demanded by theory if the value of the Committee of the German Chemical Society, Te = 127, were to be taken instead of Te = 127.5, the value of Clarke and of Richards.

ART. XIII. — *An Iodometric Method for the Estimation of Boric Acid*; by LOUIS CLEVELAND JONES.

[Contributions from the Kent Chemical Laboratory of Yale College—LXXXV.]

IN a recent article,* I have described a process for the alkalimetric estimation of boric acid, depending upon the formation of a strongly acidic compound when boric acid and a polyatomic alcohol are placed together in solution. The method in brief consists in destroying the free mineral acid in a solution containing boric acid, by means of a mixture of potassium iodide and iodate, bleaching the liberated iodine by sodium thiosulphate, adding the indicator phenol phthalein and sufficient standard solution of caustic soda to give a faint alkaline coloration, bleaching by a small amount of mannite and adding caustic soda again to alkalinity, and thus alternating with mannite and alkali until the alkaline coloration produced is permanent. The amount of sodium hydroxide used represents the amount of acidity developed by the influence of the mannite upon the boric acid present, according to the hypotheses that the molecule B_2O_3 acts as two molecules of a univalent acid, $HO \cdot BO$.

On making further study of this reaction, I have found that the acid developed by the combination of boric acid and mannite is, under certain definite conditions, sufficiently strong to liberate, quantitatively, from a mixture of potassium iodide and iodate, the amount of iodine required on the supposition that each molecule of metaboric acid ($HO \cdot BO$) acts in a manner similar to a univalent mineral acid under the same conditions. ($5KI + KIO_3 + 6HOBO = 3I_2 + 6KOBO + 3H_2O$.) Obviously, this reaction depends upon the behavior of the acidic boromannite compound as a strong acid, stronger than acetic, tartaric, or citric acid; for these acids have been found by Furry† to be incapable of liberating iodine regularly from a mixture of iodide and iodate. Conditions which tend to increase the acidic activity of this compound are concentrated solutions and moderately low temperatures.‡

Glycerine acts in general as mannite to produce acidic compounds with boric acid; and in a preliminary way, the relative acidity of the products formed by these two polyatomic alcohols with boric acid may be indicated by the results of two experiments in which the iodine liberated from a mixture of

* This Journal, vii, 147.

† Am. Chem. Jour., vi, 341.

‡ Magnanini Gaz. Chim, xx, 428, xxi, 134, and Lambert, Compt. Rend., cviii, 1016, 1017.

potassium iodide and iodate, proportionately to the time required for the liberation, is taken as a measure of the strengths of the acids developed.

Equal amounts (10cm^3) of a standard solution of boric acid, prepared from the anhydride,* were drawn into separate Erlenmeyer flasks and a neutral solution of iodide and iodate added to each in an amount sufficient to liberate iodine in quantities corresponding to the acid used. One solution was treated with glycerine enough to constitute one-half the entire volume of the liquid: mannite (about 5 grms.) was added to the other. The thiosulphate required, immediately and after definite periods of time, is shown for each solution in the following table:

TABLE I.		
B_2O_3 solution (10cm^3) with mannite. Thiosulphate required.	Time.	B_2O_3 solution (10cm^3) with glycerine. Thiosulphate required.
18.60 cm^3	immediately	8.48 cm^3
21.30 "	after 15 minutes	10.50 "
22.00 "	" 30 "	11.15 "
22.05 "	" 2 hours.	11.60 "

The solution of boric acid contained 7.706 grm. per liter. The thiosulphate was .0999 normal. According to theory, the amount of thiosulphate required for 10cm^3 of the boric acid solution is 22.02 cm^3 . From these data we may observe that at the end of 30 minutes, in the solution containing mannite, practically the theoretical amount of thiosulphate had been used, while only about 50 per cent of that amount had been required to bleach the iodine liberated by the glycerine compound. Obviously, mannite forms with boric acid a more acidic compound than glycerine, and, from the indication given in the above experiments, may be relied upon, under certain conditions, to liberate the theoretical amount of iodine. If, from the iodide and iodate used to destroy the excess of mineral acid and already present, the boric acid, upon the addition of mannite does liberate iodine regularly—as the previous experiments seem to indicate—this liberated iodine should form a most convenient measure of the boric acid present.

On studying the conditions requisite for the complete liberation of iodine according to theory, several important points have come to light.

It has not been found possible under any conditions to rely upon the immediate liberation of the full amount of iodine: a

*The recrystallized hydrous boric acid should be fused in a platinum dish and, after cooling and breaking into small pieces, the desired amount placed in a small weighed platinum crucible and again fused until no more water escapes. After cooling and weighing, the boric oxide may be separated from the crucible, or with it placed in warm water, dissolved and made up to a definite volume.

certain period of time is required for the completion of the reaction. When the solution is of small volume and saturated with mannite, the reaction goes to the end most quickly—sometimes almost immediately—but there is this limitation which must be made emphatic, viz: that if the solution of boric acid is too concentrated—near saturation—the boric acid alone, when the iodate and iodide are added to destroy any other free acid present, throws out some iodine and on bleaching with thiosulphate a starting point is obtained at which some of the boric acid has already entered into combination. The amount of iodine thus liberated by the boric acid is, however, not large, and if upon the addition of the iodide and iodate, the iodine thrown out by the free hydrochloric acid present is immediately bleached by thiosulphate and the analysis proceeded with from this as the neutral point, even in concentrated solutions the error is almost inappreciable. If, however, considerable time intervenes between the adding of the iodide and iodate and the determination of the neutral point by thiosulphate, as much as several milligrams of boric acid may have liberated its amount of iodine and is, therefore, not capable of being registered by thiosulphate after the addition of mannite. This difficulty was not met with in those experiments in which the iodide and iodate were added at a dilution little greater than that of the standard solution used (7.738 grm. per liter), but in an attempt to estimate the boric acid in colemanite, where the solution was kept as concentrated as possible, hoping in this way to decrease the time required for the complete liberation of iodine, low values were obtained; that is, a false starting point was used.

The dilution found most convenient at the time of adding the iodide and iodate is not less than 25^{cm}³ for each decigram of boric acid (B_2O_3) present and should not be much greater than two or three times that amount. This limitation as regards volume is equally applicable, whether after obtaining the neutral point and treating with mannite, the boric acid is to be measured by a standard solution of alkali as before described or as here by the iodine liberated. As has been suggested, a large volume, even though saturated with mannite, prolongs the time of standing necessary and increases the effect of carbon dioxide upon the iodide and iodate present, for carbon dioxide, whether derived from the atmosphere or existing dissolved in the solution, upon standing, slowly liberates iodine. The amount, however, is small and, in the time required for the completion of the process, has never been found equivalent to more than a single drop of the solution of thiosulphate used. Even if the material to be analyzed contains carbonates, after acidifying in concentrated solution and shaking

vigorously the small amount of uncombined carbon dioxide remaining has almost an inappreciable effect upon the results. The length of time required for the liberation of the theoretical amount of iodine in a solution of the volume suggested above, is 20 to 45 minutes, and at the end of 45 minutes standing in a solution saturated with mannite the reaction may be considered complete. During this period, however, it is well to keep the solution cool—at zero will do no harm—and shake occasionally to insure thorough mixture. The free iodine would tend to escape upon standing unless kept in a closed flask, but it is more convenient, immediately after the addition of mannite, to treat with an excess of the standard solution of thiosulphate—8 or 10^{cm}³ more than the amount required to bleach the iodine liberated, and at the expiration of 40 to 60 minutes titrate back with $\frac{n}{10}$ iodine. The strength of the thiosulphate solution found most convenient is $\frac{n}{5}$, while the use of iodine of one-half this strength ($\frac{n}{10}$) enables the error of reading to be correspondingly diminished. In solutions of the volume recommended the addition of starch to give the indication with iodine is unnecessary and even detrimental, since a single drop of one-twentieth normal iodine in excess is sufficient to give a strong lemon coloration, while in the presence of starch an indefinite dirty red first appears and remains until the blue is brought out by the further addition of iodine.

With these observations in mind, a series of experiments was made in which the standard solution of boric acid was drawn into an Erlenmeyer flask, containing a small amount of free hydrochloric acid and made up to a definite volume. To bring the conditions to those of an actual analysis about 1 gm. of crystalline calcium chloride in solution was also added. Potassium iodate (5–10^{cm}³ of a 5 per cent solution) and iodide (3–5^{cm}³ of a 40 per cent solution) were added, and the iodine liberated by the hydrochloric acid, barely bleached and again brought to coloration by iodine. Mannite was added to saturate the solution, an excess of standard thiosulphate put in, and the solution set aside for various periods of time, at the end of which the excess of thiosulphate was titrated by iodine and the amount of unrecovered thiosulphate taken as a measure of the boric acid present.

The thiosulphate used was 0.198 normal and the iodine 0.0996 normal. The solution of boric acid contained 7.733 gm. per liter.

TABLE II.

B ₂ O ₃ taken. cm ³ .	Thio. taken. cm ³ .	Iodine taken. cm ³ .	Time of standing.	Volume. cm ³ .	B ₂ O ₃ taken. gram.	B ₂ O ₃ found. gram.	Error. gram.
A							
28.00	32.00	1.88	0:30	28	0.2165	0.2168	+0.0003
27.03	32.00	4.37	0:27	27	0.2090	0.2081	-0.0009
27.02	31.97	4.04	1:00	27	0.2089	0.2090	+0.0001
B							
27.06	32.04	3.88	1:00	50-60	0.2093	0.2101	+0.0008
27.02	32.02	4.40	1:00	"	0.2089	0.2081	-0.0008
27.04	31.72	3.39	1:00	"	0.2091	0.2096	+0.0005
C							
27.01	31.53	2.88	2:00	"	0.2089	0.2100	+0.0011
26.05	31.01	4.01	3:00	"	0.2014	0.2025	+0.0011
D							
27.00	31.00	2.12	0:30	"	0.2088	0.2089	+0.0001
27.00	32.00	4.05	0:30	"	0.2088	0.2092	+0.0004
26.01	32.02	6.20	0:30	"	0.2011	0.2018	+0.0007
27.03	31.01	2.21	0:48	"	0.2090	0.2087	-0.0003
27.05	31.89	3.81	0:45	"	0.2092	0.2093	+0.0001
26.07	31.02	4.14	0:40	"	0.2016	0.2020	+0.0004
27.00	32.04	4.30	0:40	60	0.2088	0.2086	-0.0002

These results are so regular that the method seems worthy of high commendation, and especially since the standard solutions, thiosulphate and iodine, upon which the process depends, are so easily prepared and generally at hand.

The full method of procedure recommended is as follows: The borate is dissolved in as small volume and as little hydrochloric acid as possible, shaking well to remove free carbon dioxide and diluting so that, at the time of adding potassium iodide and iodate, there shall be approximately 25-50^{cm}³ of solution for each decigram of boric anhydride present. The greater part of the excess of hydrochloric acid in the solution is destroyed by sodium hydroxide and the use of litmus paper, leaving the solution distinctly acid in reaction. Potassium iodide (3-5^{cm}³ of a 40 per cent solution), and iodate (5-10^{cm}³ of a 5 per cent solution) are added in excess of that required to liberate iodine in an amount corresponding to the hydrochloric acid and the boric acid present. The iodine liberated by the free hydrochloric acid is bleached by a small amount of a strong solution of thiosulphate, and after agitating to insure thorough mixture, iodine is added to faint coloration. Sufficient mannite is now used to saturate the solution—about 10-15 gram. for a volume of 50^{cm}³—and sodium thiosulphate added in standard solution 8-10^{cm}³ in excess of that required to bleach the iodine immediately thrown out by the mannite.

The solution is again brought to saturation, if necessary, by mannite and after standing in a cool place for 40–60 minutes, titrated with decinormal iodine to determine the excess of thiosulphate present. In the manner described, specimens of crude calcium borate and crystals of colemanite were analyzed with the results given below.

The solution of thiosulphate used was 0.19939 and the iodine 0.0996 normal.

TABLE III.

Calcium borate.

Mineral. gram.	Thio taken. cm ³ .	Iodine taken. cm ³ .	Time standing.	Volume of solutions. cm ³ .	B ₂ O ₃ found. gram.	Per cent.
0.4015	35.05	4.75	1:00	40	0.2280	56.92
0.4010	35.34	5.23	2:00	45	0.2283	56.94

Colemanite.

0.4002	32.00	5.50	1:30	50	0.2043	51.04
0.2513	32.01	7.36	1:00	40	0.1279	50.91
0.4007	33.03	7.72	:50	65	0.2036	50.81

These results show little variation and in the case of colemanite correspond closely to the theory 50.97 per cent. The process is convenient, generally applicable and accurate within the ordinary limits of analysis.

ART. XIV.—*A Method for the Detection and Separation of Dextro- and Lævo-rotating Crystals, with Some Observations upon the Growth and Properties of Crystals of Sodium Chlorate*; by D. ALBERT KREIDER.

Two properties of optically active crystals are available for their detection and separation. First, the sense of the optical activity itself, and second, the hemihedral structure which, in many cases at least, differentiates the enantiomorphic forms. While it is possible, in some cases, as in the separation of the dextro and lævo tartaric acids by the crystallization of the sodium-ammonium racemate, according to the method of Pasteur, to pick out the two sets of crystals by taking advantage of their hemihedral structure, this is rarely if ever the case with crystals of sodium chlorate, which in many respects is the most desirable substance to employ in certain investigations upon optical activity.

In these crystals it is only rarely that the hemihedral pyramidal face which distinguishes the dextro from the lævo form, is sufficiently well developed to enable one to distinguish thus between them. Indeed in not a single set of the many crops of crystals which the writer has grown has there been any considerable number of crystals showing even traces of this face. The crystals commonly grow in rectangular forms; these vary greatly in shape, some being cubical, but almost without exception they are flattened and very generally elongated, with the hemihedral faces rarely showing.

Dependence must, therefore, be placed upon their optical properties, and this involves the use of the polarimeter or polarization-microscope, both of which are expensive and unsatisfactory for this purpose, inasmuch as only one crystal at a time can be examined and even then for a decisive test must be of considerable size.

In the course of an extended investigation upon related subjects which involved the separation of the two kinds of crystals, some of the results of which have been published in a recent communication from this laboratory,* I have been impressed with the inconvenience and tedium of the methods usually employed. My efforts to devise some means of effecting the separation, which would be more expeditious and at the same time sufficiently delicate, have resulted in a very simple arrangement of apparatus the parts of which may be found in any laboratory and which makes it possible to examine a whole crop of crystals in a glance or to separate them with ease. Moreover, it permits of the examination or determina-

* This Journal, vol. vi, p. 416, 1898.

tion of the optical nature of the crystals during their growth or at the instant of their appearance, without disturbing them in the least; thus enabling me to decide a point which had previously been open to question. It is also more delicate than any polariscope I have ever used.

The instruments employed for the determinations recorded in the article referred to were of the type in which a bi-quartz or half-shadow field is used, as in the well known Scheibler and Laurent polarimeters; various efforts to fit up something simpler having proved futile.

It is rather surprising to find others still employing the polarization-microscope for this purpose when the polarimeter is so much more satisfactory. After being adjusted to the tint of passage, a very small crystal simply held in the field of view by a pair of forceps or, if desired, moved from one to the other half of the illuminated disc, instantly and without further adjustment, reveals the sense of its rotation. But the objection to its use, as well as to that of the polarization-microscope, is that it necessitates the handling of each individual crystal of every crop, which when many are involved demands a great deal of time and labor.

The characteristic feature of the device which I proceed to describe, is a larger field of view than that of the other instruments, and one of uniform color of such a tint that when a mixture of the crystals is placed in it they assume different colors sufficiently striking to permit of their being easily distinguished and separated. It consists of two Nicol's prisms and some optically active substance, which latter may as well be a crystal of the kind to be experimented upon. I have also used quartz sections, but greater sensitiveness seems to result from the employment of the sodium chlorate crystal if it is sufficiently transparent. This will be appreciated as a perfectly satisfactory and economical substitute for the more difficultly attainable bi-quartz or simple quartz section, where the latter are not at hand. The crystal is mounted over the polarizer and observed directly through the analyzer. If the Nicols are crossed and the crystal then inserted between them, light will of course be transmitted, and if white light be employed, by rotating the analyzer, as is well known, the various colors complementary to that extinguished will appear in the order of the short to the long wave-lengths, if turned to the right, when a dextro-rotating crystal is employed and in the reverse order, if turned to the left; so that by suitable adjustment the desired color can easily be produced, as is explained below. If the crystal is thick enough, say one to two millimeters, this will suffice to reveal its nature; for if dextro, the blue color will appear shortly on turning to the right and if lævo, blue will appear by turning to the left.

However, this arrangement would not be sufficiently sensitive for smaller crystals and moreover necessitates adjustment of the analyzer.

But if now the crystal is mounted over the polarizer, and the analyzer be so adjusted as to bring into the field the blue color and then turned *just* enough to cause the blue to merge into purple, a very sensitive field is obtained. All that is required then is to insert a crystal, ever so small, between the analyzer and "field crystal," whereupon either the blue will be restored or a deeper red obtained. In the first case the rotation of the crystal is evidently the same as that of the field crystal, and in the other case, the opposite. For larger crystals the change of color is only greater and not less certain in its evidence as to the optical properties of the crystal under investigation.

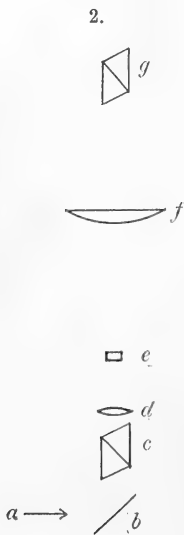
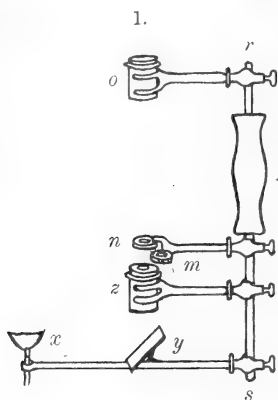
It is thus only necessary to select some clear and good-sized crystal whose rotation may easily be determined as above stated and then to use this crystal as the "field crystal." Without any change after the first adjustment above described, various crystals may now be brought into the field of view and the color they assume will instantly disclose their nature. This may be facilitated by spreading them on a long piece of glass, which may then be drawn through the field, and if it is desired to separate them, all those which, for example, turn blue may be picked out. This is extremely sensitive; the merest specks, if of the same rotation as the field crystal, being revealed. Those of opposite sense are less easily detected; but in using the device I have usually employed two field crystals of opposite rotation, separately mounted, as shown at *m*, *n*, fig. 1, so that either could be swung into the field and the analyzer adjusted. This however is only rarely desired and then merely for confirmation, where a considerable number of very small crystals occur.

The sensitiveness may be further increased by placing the very small crystal in the field and then turning the analyzer to and fro over the turning point of color, when the speck of a crystal, and its optical nature as well, will be revealed more easily by the color there preceding or lagging behind that of the field. In this way I have often been able to locate and study tiny crystals in the solution which were so small as to escape detection by reflected light.

Fig. 1 illustrates the arrangements of the parts of the apparatus just described: *p* is a wooden handle through which passes the brass rod *r s*, to which are fastened the universal clamps *o* and *z*, which hold small, hollow, wooden cylinders turned to fit the mounted Nicols; *m* and *n* are respectively the dextro and lævo crystals of sodium chlorate, chosen for transparency and sufficient thickness, say 2 to 4^{mm}. They are

mounted in cork discs which permit of either one being easily brought in or out of the field; y is a mirror which reflects the light from x vertically into the polarizer. By employing a long rubber tube to supply x , the apparatus is made portable and hence specifically adapted to observations of crystals during growth, by simply moving it so as to bring the flat-bottomed, shallow beaker containing the crystallizing solution between o and n . The beakers were held between two long supports which enabled one to see through the solution vertically; whence by simply moving the apparatus so as to include one after the other, observations could be taken without any disturbance of the crystallizing solutions.

The most satisfactory arrangement, however, is that which I have employed to enlarge the field of view, so that a whole crop of crystals could be examined at once; the number of each counted or separated by pushing to one side or picking out, as desired. Here, as in the first form, the line of sight was vertical. Fig. 2 shows the arrangement of the parts, which were simply held by universal clamps to an upright rod. The source of light was an Argand or Welsbach burner, sending light in the direction from a to the mirror, b , which reflects the light vertically into the polarizer, c . Upon the Nicol was placed a double convex lens, d , of short focal length, and in its focus was fastened the field crystal, e , of sodium chlorate mounted in a disc of cork. Thus all of the light was subject to rotatory polarization and formed a strongly diverging beam. Where the cone of light had a section of about 7 or 8 cm in diameter, a plano-convex lens, f , of longer focal length, was placed, with the plane side up, and upon this was laid a sheet of glass, which acted as a table for the crystals to be investigated. Thus the light was spread and again converged, the crystals occupying the broadest part of the illuminated path. At the focus of the light from the second lens was placed the analyzing Nicol, g , through which the crystals were viewed directly, by bringing the eye close to g . Upon turning the analyzer, the



crystals undergo the expected change in color and are beautifully differentiated. During the turning they may all change color, but never so as to leave the result uncertain. For it is evident that, if the field crystal is selected so as to be thicker than any of the regular crop, the crystal examined can only increase or diminish its effect but never reverse the rotation. Hence the blue color will only appear at the two characteristic points in rotating the analyzer through 360° . But if this condition is not fulfilled, then a thicker crystal of opposite rotation would, at some point, turn blue, just as would a crystal of the same rotation whose thickness was the difference between the field crystal and the one under consideration. Usually the field crystal was 3 or 4^{mm} thick. The crystals grown rarely exceed this thickness, and if they do, their determination affords no difficulty by the simple use of the two Nicols as before stated.

If the analyzer be adjusted so that the smallest of the blue crystals is distinctly blue, then if the field crystal is 3^{mm} thick, a crystal of the same kind 10^{mm} thick would still have a bluish tint in this field, while a lævo crystal of that size would be distinguished by a yellowish tint, or at least lack the bluish tint. This of course is an extreme test, the crystals never growing to that thickness under ordinary conditions: but it gives some idea as to the range within which the detection may be made.

Manifestly, the greatest efficiency of this device would only be obtained when the crystals under examination are shielded from diffused light: which, in my work, was accomplished by aid of a piece of dull black paper, or by working in a moderately dark room.

The Growth of Crystals.—It may be worth while here to add some of the results which the writer has obtained in a little investigation of the causes which determine the resultant optical activity of a crop of these crystals, to which Professor Japp's inaugural address, and the discussion to which it gave rise, adds some interest.

First, I have to add to the evidence adduced by Marbach,* Grenetz† and Landolt‡ in favor of the optical neutrality of the ultimate molecule of sodium chlorate, the results of a number of experiments in which, starting with only one kind of crystal, I have obtained, by repeated recrystallization, successive crops of crystals whose resultant rotations, i. e., the excess of dextro or lævo forms, bear no connection whatever with that of the original lot. For example, I have selected a number of pure dextro crystals and allowed their solution to crystallize by spontaneous evaporation. The dextro and lævo crystals of the crop were then separated, counted and weighed; after which they were again mixed and dissolved. These were then allowed to recrystallize and the whole process repeated. But the

* Pogg. Ann., xci, 487.

† Ber., xxix, 2, 2410.

‡ Compt. Rend., lxvi, 855.

results were in no respects different from those obtained when an equal quantity of both crystals were taken at the start. The same was done with lævo crystals and with a number of independent lots. In one case, starting with pure lævo crystals, a crop having eighty per cent of dextro crystals was obtained and upon recrystallization gave an excess of lævo. To record the results in detail, is hardly worth the space. It may simply be said, that there is no connection whatever with the 'optical activity of the original crystals and that of the new crop. This will of course be true only when the crystals are thoroughly dissolved or the solution filtered before recrystallization, since any nucleus left in it would affect the result, as the following experiments prove.

In the second case, as has previously been pointed out, when a crystal of one kind is placed in a saturated solution, the resultant optical activity of the crop of crystals is always the same as that of the crystal inserted; the percentage, however, seems to depend upon the rate of precipitation. This seems to point to the influence of the first crystal formed, as the cause of the excess of one or the other kind in the crop. To further investigate this, I have grown crystals by carefully observing the optical properties of the first one formed. The apparatus illustrated in fig. 1 is admirably adapted to this purpose, since it permits of the observations without the slightest disturbance of the crystallizing solution. Owing to the irregularity in the rate of formation of the crystals under varying conditions of temperature and humidity, a series of such results is tedious and difficult; demanding the continual presence of the observer, in order that the determination should be made at the moment of the appearance of the first crystal. For example, one experiment which was started at noon by filtering a portion of a saturated solution—in this case one which had stood over an excess of crystals for several weeks and had been well shaken several times daily—had formed no crystals by 9 o'clock of the next day; though by 10.30, nine fair-sized crystals had developed. In other cases they appeared during the same afternoon or night. Moreover, any particles of dust settling on the solution form nuclei, about which clusters of crystals are apt to develop and in such cases grow more rapidly than those under the liquid, though the latter may have been first to appear. The conclusion of many experiments was prevented in this way, as well as by the simultaneous appearance of a number of crystals. However, by taking precautions against dust and by securing approximate uniformity of temperature, etc., a number of experiments were successfully concluded: and in every single case where the first crystal formed developed appreciably before others appeared, the resultant activity of the crop was invariably that of the first crystal.

ART. XV.—*The Devonian Interval in northern Arkansas;*
by HENRY S. WILLIAMS.

IN numerous places in northern Arkansas the evidences of an unconformity separating the Silurian from the overlying Carboniferous are very clear. In some cases there is no rock-material separating these two grand terranes. In other cases there are greenish shales, or coarse sandstone, with polished grains and rounded nodules of black shale; and in the western sections the interval is occupied, in part, by a black shale, the *Eureka shale* of the Washington County report.* The sandstone when present is called the *Sylamore sandstone* in the various reports. The materials discussed in this paper are from the following localities. The numbers before the names are locality numbers of the United States Geological Survey, under which the materials studied are catalogued preparatory to final deposit in the National Museum.

1246. Buck Horn, Stone Co., Arkansas.	1238. St. Joe, Searcy Co.
1281. Roasting Ear Creek, Stone Co.	1277. Cave Creek, Newton Co.
1278. Rush Creek, Marion Co.	1410. Eureka Springs, Carroll Co.
1282. Dodd City, Marion Co.	1279. War Eagle Creek, Washington Co.
1414. Long Creek, Searcy Co.	1291. Buffalo Fork, Newton Co.

On passing westward from Batesville, the first locality, from which specimens representing this interval have come, is 3 miles north of Buck Horn, Stone County (No. 1246 A) on Cagen Creek.

No. 1246. Buck Horn, Stone Co.

This station was first reported by Dr. Branner as "section 3, 14 N., 9 West, at John Greenway's; over 4 feet black shale overlaid by one foot that weathers red." It is 82/11 of Hopkins's report of '89, Oct. 3d; and was reported by me in letters Nov. 9, '89, as "a black shale very similar to the Berea of Ohio." Afterwards, Mr. Stuart Weller was sent into the region and reported the exact sections from Cagen Creek, 3 miles north of Buck Horn, July 13, 1891.

Study of the fossils in connection with the sections resulted in the following interpretation, viz:

- 1246 A3. A red marble = St. Joe marble. (= Eocarboniferous.)
A2. Black shale with *Lingulas*, several feet thick. (= Eureka shale.)
A1. A pink marble with no fossils seen, probably the Polk Bayou limestone. (= Trenton).

This section is in the hollow on the south side of the creek. The section B was made 200 yards east of A; and B' = A';

* Ann. Report, 1888, vol. iv, p. 26.

B2 = A2, but B2 is a hard, greenish black rock with rounded black pebbles; B3 = A3. The 3d section is taken at a point about half a mile up the creek, on the east side. C1, 2 and 3 correspond to A2; and consist first of black shales, with a band of hard black limestone 4 inches thick (C2) in the midst. This is followed above by the St. Joe marble (C4), and is capped by Boone chert (C5).

At the Buck Horn locality the interval, between the pink Silurian limestone which contains no fossils and the overlying red Carboniferous marble, contains a few feet of typical black shale, such as represents the Devonian interval in Tennessee. It contains a small *Lingula* which may be called *L. spatulata*, until some one succeeds in determining where to draw the specific limit between the minute forms of the Genesee shale of New York and the several forms which succeed it in the black shale strata of the Waverly of Ohio.

Associated with the *Lingula* are Conodonts, as in the Genesee and similar shales in New York state. Two hundred yards east of this section (at 1246 B), the same interval is occupied by a hard, siliceous, greenish-black rock with very hard, rounded black nodules, with no fossils seen. In both of these interval-filling rocks are found the coarse, polished, siliceous grains so characteristic of the Sylamore sandstone, indicating identity of origin for the three kinds of material. The black shale may be called the *Eureka shale*, stratigraphically speaking; but its identity paleontologically has not heretofore been established.

The next place from which evidence has been seen is Roasting Ear Creek, 8 miles southeast of Big Flat, in the western part of Stone County.

No. 1281. Roasting Ear Creek, Stone Co.

The materials examined from this section were collected by Weller, from a point 8 miles southeast of Big Flat, July 10, 1892. The fossils in the red limestone (A1) were supposed by him to have fallen down. They are all Trenton fossils, showing the rock to be the Polk Bayou limestone. The shale (A2) contains the same kind of black pebbles seen in 1246 B2.

Here the interval-filling material is a green siliceous shale, more or less calcareous, containing fragments of shells and of what appears to be broken fish teeth, and well-rounded pebbles or nodules of hardened black shale; everything too much broken and polished to indicate the genus or even class of organisms with certainty. This rests immediately upon red marble of Trenton age, the Polk Bayou limestone. The overlying rock is not reported.

About twenty-five miles northwest of this section is seen another outcrop at the "narrows," 3 miles from the mouth of Rush Creek, in Marion County.

No. 1278. Rush Creek, Marion Co.

The section 1278 was taken along the creek, opposite the mines, by Weller, July 9, 1891. The limestone (A2), coarse-grained, pinkish, containing Trenton fossils, is thus shown to be the *Polk Bayou limestone*. The limestone below (A1 and B1) is probably the same as the heavy bedded blue limestone, and, though no fossils are seen in it, the probability is that it is the *Izard limestone* of the Reports. The coarse saccharoidal sandstone (A3 and B2) is the *Sylamore sandstone*. The red marble (A4 and B3) contains a few fossils of Carboniferous age, and is therefore the *St. Joe marble* of the Reports. Section 1278 B is taken on the hill, three miles from the mouth of Rush Creek. The evidence that the Sylamore sandstone represents the Black shale (Eureka shale) is clear upon comparing the sections 1278 and 1246. This interval-material is pinched out to almost nothing in the following section.

Another section was seen at Dodd City.

No. 1282. Dodd City, Marion Co.

The section reported was taken at a point 3 miles north of Dodd City, Durst's spring, by Weller, July 23, 1891. He reported that the red marble (A3, *St. Joe marble*) rests directly upon the blue-gray limestone (A2), which contains fossils showing it to be the *Polk Bayou* (Trenton) limestone. Below it is a bed of the Ordovician, *Saccharoidal sandstone*. No rock was discovered in the interval, but the gap was seen separating the two limestones, and the upper one is identical (so far as the characters of the limestone, without actually seeing fossils, can be depended upon) with the *St. Joe marble* of the other sections. We see here a case of a true interval, representing all the time from the Trenton to the Carboniferous, certainly later than the Chouteau, and without sufficient disturbance of the horizontality of the rocks to make the unconformity apparent.

A few miles west of the Roasting Ear Creek section, on Long Creek, near a place called Providence, Searcy County (1414 A), is seen another section, with the Silurian terrane terminated by *St. Clair limestone*, and then about two feet of interval, filled with characteristic *Sylamore sandstone* with its polished siliceous grains, and black rounded nodules.

No. 1414. Long Creek, Searcy Co.

This section, taken along the bank of the creek, was visited by Dr. Branner and myself; and when it was first seen, it was quite impossible to imagine that the two limestones were not actually continuous. The beds lie nearly horizontal, and a stretch of their exposed edges is in sight for several hundred feet. The interval (A2) was discovered only after search. The fossils in the limestone (A1) belong to the Niagara fauna

of the *St. Clair limestone*. The *Sylamore limestone* (A2) wears away faster than the limestone and shows a retreat in the ledge of exposed rocks. When examined, it is found to be the typical Sylamore sandstone composed of polished sand grains, and pebbles of black shale and fish-bone fragments. Immediately above it comes, without apparent change in the plane of bedding, the *St. Joe marble* (A3) containing Carboniferous fossils.

Still further west is the St. Joe section.

No. 1238. St. Joe, Searcy Co.

In this section, the green shale, associated with the Sylamore sandstone (A4 and 5), contains nodules like those in the sandstone; and the *Lingulas* contained in them, and fragments of *Lingulas* in the black nodules, point to a common origin for the varying kinds of deposit, i. e., black shale, Sylamore sandstone, and this green shale containing the black nodules. A piece of large fish-plate indicates the age to be as late as Devonian, but, in itself, does not make certain that it may not have been late Devonian, though the probability is that it belongs below the latest Devonian. At this point the termination of the Silurian terrane (A2) is Trenton limestone (Polk Bayou limestone). The interval material is, first, a few feet of green, gritty mud shaly rock (A4), including a few black, rounded, hard nodules, its upper part shaly, followed by four inches of Sylamore sandstone (A5), with its characteristic polished siliceous grains and black worn nodules. The nodules are slightly calcareous, due either to infiltration of calcite, or included fragments of shell. Some of the nodules contain pieces, and whole shells of *Lingulas*, but the structure of the nodules suggests agglutination. In one of them a grain of the polished silica is enclosed; and in another the nodule is made up of fragments of shells and oolitic grains. The sandstone is followed above by a compact, red Carboniferous limestone (A6) of thirty feet thickness. The under surface of this limestone, where it came in contact with the interval sandstone, is penetrated by, or contains black nodules like those below; two specimens were obtained partially surrounded by the crystalline limestone. The *Lingula* is like a minute *Lingula spatulata* of the New York black shales, but is rather shorter and more solidly formed than the ordinary type of *L. spatulata*. However, the variability expressed in the few specimens examined leaves no mark for differentiating it specifically from *L. spatulata*, as seen in sundry localities in the north.

In one piece of the Sylamore sandstone, a large fragment of a fish-plate was found, reminding one of the plates of *Dinichthys* of the Black shales of Ohio. But the piece is worn and crushed, and its original outlines are indistinguish-

able. The bony texture is preserved, and the fragment, 2 by 3 inches in diameter, is $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness.

In Newton County, a section was seen near the Saltpetre Cave, Cave Creek P. O.

No. 1277. Cave Creek, Newton Co.

The first specimens seen from this section were collected by Mr. Hopkins in the summer of 1890, and were marked as from Saltpetre Cave at Cave Creek P. O. In the next season Mr. Weller collected from the same section, sending in enough specimens to make out the several elements of the section. The interval-material of this section is a hard, black, shaly rock, about 18 inches thick (A2) separating the Polk Bayou limestone (A1) from the overlying red marble (A3), the St. Joe marble, which is here 10 feet thick; above it lies the cherty limestone (A4), which is called Boone chert in the Reports. The black shale (A2) contains *Lingulas* as in the St. Joe section.

The typical locality for the black shale is Eureka springs, from which the formation derives its name.

No. 1410. Eureka Springs, Carroll Co.

The full section of the rocks at Eureka Springs is given in volume iv of the Annual Reports of the Geological Survey of Arkansas for 1890.* The part of it interesting in this place is that given in my section 1410 A. A' is the top of the saccharoidal sandstone; resting immediately upon this and without any apparent change in the plane of bedding is the black shale (A2). In the section, in the midst of the city, the thickness of black shale is about four feet, with a foot above it of green shale. In some places the green shale is several feet thick. When I visited the locality, an excavation for the cellar of a building exposed a fresh cut of about six feet of the greenish shale, from which a few fossils were obtained. The black shale ran up into the green without any sharp line of sudden change, showing a continuous deposition. The black part is, however, the typical Eureka shale (A2), while the upper green part is a representative of the formation which in Tennessee is much more important and constitutes in that region the lower member of the Carboniferous system. The sandstone (A') below the Eureka shale is the Ordovician rock lying below the Polk Bayou limestone. It will be noticed that where the black shale, filling the interval, is present and thickest in the northwest it rests on the lower formations, below the Polk Bayou limestone, and the erosion has cut into the saccharoidal sandstones. It seems probable that these sandstones were the source of the polished siliceous grains

* Marbles and other limestones, by T. C. Hopkins. 1893.

characteristic of the Sylamore sandstone, and if this be a correct inference, a reason is apparent for the distribution of the Sylamore sandstone over surfaces which had not eroded so far down as this rock; since the place of sedimentation would not be the same with the place of erosion from which the materials were derived.

Further south, in the northeast corner of Washington County, Arkansas, specimens have been obtained containing a few indistinct fossils which are important in interpreting the age of this interval-deposit.

No. 1279. War Eagle Creek, Washington Co., T. 18 N., R. 28 W., Sect. 15.

The materials were collected by Mr. Weller, and the section is described as a bed of black shale (1279 A') with very little iron pyrites, containing fossils, followed immediately by a reddish-gray limestone (1279 A2) containing crinoid stems, but no distinct fossils. On the opposite bank, the black shale was found to be about 30 feet thick, but no fossils were discovered in it. The underlying rock was not seen. According to the map and descriptions given by Prof. Simonds,* this is the Eureka shale underlying the Boone chert and limestone. The fossils are in imperfect, frail and crushed condition, but have a decidedly Carboniferous aspect. They also appear to belong to the same fauna, discovered in the greenish shale (1410 M2) into which the black shale of Eureka springs gradually merges before reaching the limestone above.

Three small collections from Newton County (1291 A, B and C) indicate the same fauna in greenish shale, and the several, together, present unmistakable evidence of the Chouteau fauna of the regions further north in Missouri.

No. 1291. Buffalo Fork, Newton Co.

The materials from this region were collected by Mr. G. H. Ashley, and the localities are defined as follows, viz:

1291 A. Eureka shale, from N.W. quarter to S.W. quarter, of section T. 17 N., R. 21 W.

1291 B. At base of St. Joe marble, probably; 4 miles south of Jasper, in Henson Creek, one mile above mouth of Panther Creek, S.E., of N.W., Sect. 1, 15 N., 22 W.

1291 C. In shale on top of Saccharoidal sandstone, N. 4, of S.W., Sect. 9, 16 N., 22 W.

The fauna of the interval-filling material.—Although the fossils, obtained from the black shales, the greenish shales following them, and the nodules contained in the black shales, are very rare, imperfect and frail; a careful study of the material has

* Ark. Geol. Survey, Ann. Rept, 1888, vol. iv, Washington County, by F. W. Simonds.

brought out features more or less distinct by which their biological relations can be determined. The whole of this list may require some specific revision whenever better specimens come to light. Enough is preserved to make the generic identifications fairly certain. In determining them, great pains was taken to discover, if possible, signs of those particular characters which mark the difference between closely allied species of successive, known geological horizons. A few remarks may be given regarding the points thus ascertained regarding the more important genera.

Lingula.—In the black shale strata, and in the black nodules of the greenish shales and Sylamore sandstone, a number of minute *Lingula* were seen. These were compared with a large series of specimens from the typical Genesee shales of New York, Cleveland, Bedford, Berea, Ohio, Huron, Portage, Ithaca black shales, Harpeth shales of Tennessee, and from similar black-shale rocks of Europe. The conclusion from the study is that the forms common in the Genesee black shales of New York are the central and typical forms. These are often found almost alone. The most frequent associates are Conodont teeth and a small *Chonetes*. From these common black-shale forms the succeeding *Lingulas* differ by slight and indefinite gradation, until they reach a size five times as great as the typical Genesee types, and vary in dimensions and in thickness of shell.

The change, which is apparent in the New York sections, when the succession is distinct and clear, is from the very minute forms in the pure Genesee shale, to larger, broader and more rounded forms in the same shales; the variation in the Genesee specimens reaches a doubling or tripling of the typical size, and with modification in the general form. In the blackish shales higher up at about the Ithaca horizon, and in Portage strata when they are prevalent, and still higher in bands of shale coming in in the midst of Chemung strata, in western New York, the larger, broader, more rounded forms are seen. In the black shales in the Ohio sections, representing the upper part of the Chemung and reaching up into undoubted Carboniferous horizons, the same form is traced, increasing somewhat with the rise in horizon and as they mix with other species. Finally, we reach a form, which is represented fairly well by Meek and Worthen's *Lingula subspatulata*. The fact that the subspatulata size and form are reached in the prevalent Tennessee type has led me to think that where it occurs the horizon is well up in the series rather than in a mesodevonian horizon.

In the Arkansas case, the forms seem to me to come in near the upper limit of the Devonian, as expressed in the New

York-Ohio region, on the supposition that the modification from the minute forms to the broader, oval, flat, enlarged forms of the Carboniferous horizons is one due to gradual evolution. But I do not feel perfectly confident that this is the case. I think it more likely that the conditions of environment at the same time would find expression in something of this modification. That the species is peculiar to the kind of sediments which, in their purity, constitute the black shale, is quite evident from a wide study of their occurrences.

Cyrtina.—In the brownish-black shale of station 1279 A1 several specimens, which I refer to *Cyrtina acutirostris* Shumard, are found. Several of the specimens are much crushed, but the high beak, the attenuated upper part, and broad and rather extended mesial sinus and few lateral plications, which are not so broadly rounded as in the figure, are the characters suggesting the species. The characteristic punctations are not evident.

Spirifer.—Several species of this genus are recognized. The specimens from 1291 C (Y 200) are clearly *S. marionensis*. Those from 1279 A1 (Y 423) are crushed and only fragments, but what is evident agrees with the similar parts of perfect specimens of *S. marionensis*. This species is frequently seen in the higher beds and across the line in Missouri; it is characteristic of the corresponding shales at the base of the Carboniferous. *S. biplicatus* Hall is suggested by some crushed specimens (Y 171), but the material is too imperfect for certain identification. *S. winchelli* Herrick, cf. *S. mesacostalis*, a very perfect specimen (Y 199), resembles very closely some specimens of the smaller variety of *S. mesacostalis* from the Ithaca group (Devonian) of New York. It is the type described by Herrick, from the Waverly of Ohio, under the name *S. winchelli*. Mr. Herrick suggests the close resemblance to *S. mesacostalis*, but in a note to the writer he says that Professor Winchell considered it to be undoubtedly a distinct species.

S. ? compactus Meek.—Some crushed specimens (Y 172) from the green shales at Eureka springs (1410 M2) may belong to this species. It has the form of *pinguis* or *suborbicularis* Hall, and yet is too crushed to well make out the true proportions.

Spiriferina ? octoplicata.—Specimens (Y 173), fairly representing the character of this species, occur in the green shale at Eureka Springs (1410 M2).

Athyris is represented in the green shales (1291) by specimens, which are referred to *A. hannibalensis* Swallow (Y 201). Another specimen is referred with doubt to *A. fultonensis* Swallow, from the green shales of Eureka Springs (1410 M2).

Chonetes.—Two, and perhaps three, species of *Chonetes* occur in these shales.

C. illinoisensis.—A single specimen of this species occurs in the soft green shale (1410 M2), above the black, at Eureka Springs. It is smaller and more delicate than the typical forms of the species, but has the broad, flat, finely striated characteristics of *C. illinoisensis*. With it are associated many smaller forms, which may be of two or one species; the larger number are about the size and shape of the New York *C. scitulus*, but varying to the shape of *koninckianus*. There are other specimens with fewer plications, which approach the character of Shumard's *C. ornatus*. It is altogether probable that the specimens described as *C. ornatus*, Shumard, are the same species with these. There is considerable range of variation among the specimens before me, and it seems not impossible that they all may represent a very variable species; since the larger forms are more finely striate by bifurcation of striæ, and are flat and frail, as in the largest form which I have referred to *C. illinoisensis*. For purposes of reference, until a fuller study of the genus is made, they may stand as *C. illinoisensis*, *ornatus* and ? *scitulus*.

Productus.—One fragmentary specimen from the green shales (1291) (Y 204), though too imperfect to specifically identify, is distinctly a Carboniferous type, resembling *P. burlingtonensis* Hall.

Productus hallanus Walcott, is represented by several specimens from the green shale at Eureka Springs (1410 M2), and from the black shales at War Eagle Creek (1279 A1).

The genus *Rhynchonella* is represented, but the crushed specimens make specific identification little better than guesswork. Their resemblance to similar crushed specimens, in the Tennessee greenish shales in the same geological position, and in the Waverly of Michigan and Ohio, which are generally referred to the species *R. sageriana* Winchell, leads me to so label them. These frail, crushed *Rhynchonellas* are from the Eureka green shales (1410), and from the black shales at War Eagle Creek (1279). *R. acuminata* var., is also seen in the green shales in Newton County (1291).

Orthidæ.—Of this family, several genera are represented. *Rhipidomella* (Oehlert) is represented by forms which are generally catalogued under the name *Orthis michelini* L'Eveillé; but, though crushed, the specimens before me are decidedly broader than that species, and thus are more like the Devonian types of *O. Vanuxemi* or *penelope*. In outline, they are close to that of *O. Oweni* Hall,* but have no trace of the broad fold

* Paly. N. Y., vol. viii, Brachiopoda I, p. 342, fig. 19 of plate vi.

and sinus of that species. They are evidently the same species figured on Plate VI A of the New York Volume VIII, Brachiopoda I, and called *Orthis* sp.? (compare *O. penelope*), from the Waverly group of Granville, Ohio.

As a name, I think it is probable that Hall first distinguished the species in question, in the Iowa Report of 1858,* under the name *Orthis michelini*, var. *burlingtonensis*, so that they should be called *Rhipodomella burlingtonensis* Hall. The specimens correspond more nearly to specimens in like condition in the Burlington than to the typical *O. vanuxemi* or *penelope*, though in some features recalling the latter. Another species, *Rhipidomella thiemii* (White), is a small species, and may prove to be but a young or small form of the *burlingtonensis* species, but, as it is frequently seen of the diminished size, it is safe to refer to it as a distinct species.

Schizophoria is represented by a couple of faint impressions in the black shale of 1279 A1 (Y489). This, for purposes of identification, may be referred to *S. swallowi* Hall, with a query; sufficient evidence is present to refer it to this genus, but the crushed condition of the specimen makes it impossible to tell what its original form was.

Strophomenidæ.—Among the Strophomenidæ, a few distinct representatives of the *Leptaena rhomboidalis* have been seen in the green shale of 1291.

Terebratuloid shells are difficult to identify, even when perfect, from the exterior alone, but a crushed fragment in the green shale of (1279 A1) suggests strongly the form *Dielasma burlingtonense*.—We may refer to this as a possible species of the fauna.

In addition to the specimens whose generic affinities may be distinguished, there are *Conodont teeth*, fragments of *fish bones* which must have belonged to large mailed fish, and *Crinoid stems*.

When the whole fauna is critically examined, though the specimens are nearly all in very imperfect, distorted condition, enough may be made out of their zoological affinities to settle the question of general horizon. The black shale, when it stands out distinct with a limestone below and above, presents a fauna which would link the horizon with that of the Genesee black shale of New York. But when we examine it, where followed gradually by a green shale, becoming finally calcareous, and running up into thin, shaly limestone beds with the green shale alternating with it, before the pure limestone enters the section, the evidence of precise horizon is less positive. In such a case the fact, that the Genesee black shale has a definite geological horizon in the New York sections, must not be

* Geol. of Iowa, vol. i, part 2.

allowed to limit the range of the fauna it contains. The fauna, which is well exhibited as soon as the green shales are in force, is always of Carboniferous type; and in one case, we have a black shale also containing the same fauna, which I refer to the black shale of the War Eagle Creek section (1279 A1), thus clearly indicating the stratigraphical continuity of the green and black shales of the general region.

The fauna associated generally with the pure black shale sediments in Arkansas, and in other regions in the south, is restricted to very few species, of which the *Lingula* is the most frequent often associated with *Conodont* teeth. This is also characteristic of the Genesee black shale of New York. My conclusion from the study of the whole problem is, however, that the fauna of the Genesee black shale, which has a definite limited position in the New York section, is a fauna of wide geological range, and is characteristic of the black shale conditions of sedimentation rather than of the particular limited horizon represented by the Genesee formation. The fauna in these fine shales in Arkansas, terminating and following the black shales, is unmistakably much higher than the Genesee black shale of New York. Faunally, it is the correlative of the Louisiana or lithographic limestone, and is thus as late as the Kinderhook stage of the Eocarboniferous.

There can be no doubt regarding the Carboniferous age of the faunas of the typical Louisiana limestone. Its fauna is characteristically Kinderhook, Waverly, Chouteau, and it is not paleontologically correct to refer the Louisiana and Hannibal (or those Arkansas formations which belong to the same epoch) to the Devonian (as Mr. Keyes has done in the Biennial Report of the State Geologist of Missouri for 1897, page 59). The fauna of the shales terminating the interval deposits in Arkansas, is evidently the same as that seen in a similar position in the Louisiana section in Missouri, and thus belongs to the base of the Chouteau or Kinderhook group.

The age of the Sylamore sandstone and associated deposits.—

From a study of all the evidence visible, both stratigraphical and paleontological, I have reached the following conclusions regarding the probable age of the formation of this interval-material. The distinct fossiliferous deposit of black shale seen in Cagen Creek section (1246 A) cannot be distinguished paleontologically from the "Black shales" of the Tennessee, Kentucky and Indiana sections. The St. Joe sections indicate distinctly that the green shale and the Sylamore sandstone were formed at the same geological time, i. e., consecutively; and that the Carboniferous deposit, following, was formed after the Sylamore sandstone was laid down, hence that the sandstone with its nodules, and the green mud-shale associated with it,

are not later residual products of decay of the lower limestones, as Mr. Penrose explains the origin of the manganese-bearing interval-material in Independence County. Again, the black nodules contain *Lingulas* as do the black shales, and the structure of the nodules, and the evident agglutination of some of them, and the concretionary nature of the oolitic grains of which others are composed, all point to a concretionary mode of formation rather than to a simple rounding of broken fragments; while the extreme polishing and medium size with absence of finer grains of the sandstone, point to excessive erosion. Again, the fauna appearing next above this interval-material is in all cases, when covered by rock, of Carboniferous age; the species indicating generally a Chouteau fauna, in some cases later Chouteau with traces of Burlington, or Keokuk species.

The interpretation of these facts is that the typical interval-materials, the green shale and the Sylamore sandstone, were deposited after the period of the formation of the typical black shales which, along the borders of the Ozark uplift, was terminated, or actually driven outward, by the elevation of the region; that these particular deposits mark the stage of sinking again of the land and the resultant erosion which introduced the Carboniferous formations for this region; that the time was at the very close of the Devonian and beginning of the Carboniferous eras. I conclude that the explanation of the varying age and nature of these deposits is due to the sections having been taken at places at lower or higher position on the gradually sinking land, and expressing the overlap of the successively more recent deposits. This point, however, can be satisfactorily determined only by examination of the stratigraphical relations of the various formations. My judgment is based upon the relations of the various formations in the few sections presenting several of the formations in succession.

The descriptions in Dr. Penrose's Report (Ann. Rept., 1890, vol. i) stratigraphy of Independence county led me to infer a similar explanation of the facts there; but evidence was not then at hand to disprove the reference of the red limestones, lying above the interval-accumulations, to the Silurian limestone. If Dr. Penrose was correct in his reference of the upper limestone, in the section of the O'Flynn mine (p. 231, fig. 14), to the St. Clair limestone, it is difficult to discover any relationship between the Sylamore sandstone and the manganese deposit which would be included in the midst of that limestone. Among the specimens sent in by Mr. Hopkins, there is no evidence of the Silurian limestone at the O'Flynn mine, but there does appear evidence of a deposit similar to the Sylamore sandstone in connection with the so-called

manganese bed. The relationship existing between the Sylamore sandstone, which is the phosphate-bearing rock of this region, and the manganese deposits described in the Batesville region, is not yet clear.

As Dr. Branner has suggested in a latter discussion of the subject,* it would appear that the Sylamore sandstone, and the manganese deposits, are confused in some of the sections. Whether the reason for this is the wearing down of the Silurian series, so that the Devonian interval deposits were laid upon the surface of the manganese deposits (the Cason shale), or whether they have been let down by the solution of an originally intervening limestone, it is difficult to determine with the evidence now before us.

There seems to be good evidence to suppose that they are not of the same geological age. Further study of the whole problem of the deposits filling the Devonian interval in the south† has led to the conclusion that, however much erosion of the underlying Silurian formation took place, the sediments of black mud forming the shale did not begin till after the beginning of the Devonian era. The association of the fragments of thick bones of large fish with the worn Sylamore sandstone, is observed on the eastern margin of the Cincinnati plateau in Kentucky. So far as our knowledge of the range of species goes, these fish were not living till the early part of the Devonian era. The black shale following such worn material suggests a sinking of the particular region, and when the shale and the worn fragments and nodules alternate, as they appear to do in central Tennessee, it may be taken as evidence of the continuous, shallow condition of the region, which was at that time the southern extension of the Cincinnati plateau.

Note.—While preparing this report for publication, I have seen vol. iii, Part II of the Minnesota Report,‡ and notice a remark which suggests the extension of this peculiar interval deposit as far north as Minnesota. Describing the section of the rocks at Prosser's ravine near Wykoff, Fillmore County, the authors state that "Succeeding the foregoing bed [which was of uncertain age, of 6 feet thickness, regarded as Upper Silurian, the passage of which lithologically from the Richmond group (upper Cincinnati group) is described as exceedingly gradual] and followed with not very strong evidence of unconformity by Devonian strata, is a sandstone four feet thick,

* See the Phosphate Deposits of Arkansas, by J. C. Branner, Am. Inst. Min., Eng., 1896.

† See the southern Devonian.

‡ Geology of Minnesota, vol. iii, Part II, of the final report. Paleontology, 1897, p. cv.

which here and there contains large numbers of small quartz pebbles, varying between 1 and 10^{mm} in diameter. This sandstone we assume to belong to the Oriskany of New York" (p. cv). The evidence of elevation and erosion, prior to the deposit of this so-called Oriskany, is found in the absence of the formations immediately preceding the Devonian formation in complete sections. The beginning of permanent sedimentation with well-worn pebbles is what should be expected, as the land was depressed, whatever the time at which it took place. A similar thin layer of much worn pebbles and sand, separates the magnesian limestones (Ordovician) from the underlying gneiss, at a section on the southern slopes of the Adirondack at Little Falls, New York. It is followed by black mud shale with *Lingulas*, and then the regular magnesian limestone of considerable thickness. So other cases might be cited, the age of the beginning of the new sedimentation being determined by the first fossils above the abrupt change, and the unconformity may not be indicated by conspicuous modification of the plane of sedimentation. We should less expect real unconformity in the central part of a continental mass, as in the Mississippi valley region, than on the borders where the folding and faulting has been chiefly concentrated.

ART. XVI.—*Note on a New Meteoric Iron found near the Tombigbee River, in Choctaw and Sumter Counties, Alabama, U. S. A. ;* by WARREN M. FOOTE. With Plates II and III.

IN March last, the firm of Dr. A. E. Foote, Philadelphia, Pa., received from Mr. Elbert J. Brower, Keewanee, Miss., a small sample of iron which bore evidences of meteoric origin. A further correspondence resulted in the purchase by this firm, through Mr. Brower, of six masses of meteoric iron, constituting so far as known, an entire "fall." Later a lengthy but unsuccessful search and inquiry was made in the vicinity for other pieces which might have fallen.

Nothing whatever is known in that section concerning the actual fall; therefore the collection of data made by Mr. Brower was limited to securing statements from the finders and the owners of property on which the masses fell. These statements, taken in the presence of witnesses last June, are offered as a true history under Mr. Brower's affidavit, and after arrangement and elimination of irrelevant matter by the writer, are here briefly outlined.

The external appearance of the specimens is best understood by reference to Plate II, made from a photograph of the largest mass found. It resembles the usual type of siderites, the characteristic depressions and oxidization being well shown. In parts the latter assumes the form of limonite, and what is apparently an earthy hematite. The disintegration of the iron is rather marked, being accompanied by oxidization and the deliquescence of a reddish-brown fluid, lawrencite. This latter feature was remarked by the finders, when the specimens were left in the rain. The one-third decrease in weight, reported as occurring since the largest mass was found twenty-one years ago, is further evidence of instability, in the absence of any precautions for preservation.

Internal Structure.—The smaller mass (No. 5), shown in Plate III, exhibits a pronounced cleavage in one corner from which a sample, already referred to, was broken. This cleavage is probably not due to any uniform crystalline structure, but to the thin plates of a pyritiferous mineral, which are irregularly scattered through the mass. The edges of several of these plates appear as sharp lines, resembling scratches on the polished surface, their true nature becoming evident on etching. The iron is soft and takes a brilliant polish. On etching No. 5 with dilute nitric acid a cubic crystallization was disclosed by the development of minute Widmanstätten figures,

whose form could only be observed with the aid of a lens. The lines were exceedingly fine and crossed at varying angles. A notable difference is seen between the above and the markings on an etched face of one-half of No. 3 specimen, shown in the lower part of Plate III. In the latter occurs a bright bronze-gray mineral which proved after qualitative analysis to be schreibersite. It is strongly magnetic and contains considerable amounts of iron, nickel and phosphorus. This assumes the curious and novel form of large graphic characters, some of the curved branching figures terminating in angular crystallizations. While Widmanstätten figures are absent, the plessite exhibits a beautiful phenomenon, suggestive of a metallic sunstone. It presents a glistening, frosted effect, which changes with the light, due to the arrangement of tin-white flakes or fissures of the metal. Other portions of the etched plessite remain perfectly smooth from the lack of crystallization. The illustration poorly represents the oddity and beauty of the specimen, yet indicates the unique features, which establish for it a separate position among the siderites.

The Composition, as shown by an analysis made by Mr. J. Edward Whitfield, on about four grams of the clean metallic portion from No. 5, is as follows :

	Per cent.
Iron	95.02
Nickel	4.11
Cobalt	0.40
Phosphorus	0.324
Carbon	0.161
Sulphur	trace.
	<hr/>
	100.015

History of six masses, having a total weight of 43,795 grams (96 lbs. 9 oz.).

No. 1. Weight 15,019 grams. See Plate II. Said to have weighed 22,200 grams when found about 1878. Is now to all appearances a complete mass. Found in presence of J. P. Smith and C. L. Smith, by R. Y. Smith on the Pleas May property, 150 yards south of the Meridian and Tomkinsville road, on the west slope of a hill, next an uprooted pine tree, which probably dislodged the specimen from the spot in which it was buried by the fall. Location, S. W. quarter of Sec. 9, Range 2 west, Township 14, Choctaw Co.

No. 2. Weight 11,976 grams. Irregularly rounded mass. Found about 1886 by R. Y. Smith in plowing on land of G. D. Smith, on the west slope of a hill situated in the S. E. quarter, Sec. 5, Range 2 west, Township 14, Choctaw Co.

No. 3. Weight 9,215 grams. Irregularly rounded piece. Found about 1886 by William Howington on land of G. D. Smith on top of a hill in S.W. quarter of Sec. 4, Range 2 west, Township 14, Choctaw Co. (about one-quarter mile south of No. 2).

No. 4. Weight 3,568 grams. Flat, oblong piece, showing depressions. Found by Henry Wilkerson on property of George Bennet, at the side of a ten foot cut in the Gaston and DeSotenville road, which there traverses the east side of a hill. Location, about 2 miles south of Gaston in the N. E. corner of Sec. 31, Range 2 west, Township 16, Sumter Co. This specimen, like No. 1, was buried at some depth by the fall, and was unearthed by the wearing down of the public road at this point.

No. 5. Weight 3,260 grams. Egg-shaped mass shown in upper half of Plate III. Plowed up by W. C. Moore on land of R. L. Moore, situated in the N. E. corner of Sec. 19, Range 2 west, Township 15, Choctaw Co. Found about 400 yards west of the Gaston and DeSotenville road, on west slope of a rocky hill, one-quarter mile S. W. of Jachin.



The numerals show the location in which the masses enumerated in the text were found.

No. 6. Present weight 757 grams. Flat oval. Found about 1859 or earlier by Ben Johnson on land of M. E. Grace. Presented to D. F. Alford, who made a horse-shoe nail from a portion of it (original weight not known). Found about one mile north of Jachin, just east of Gaston and DeSotenville road, in S.E. corner of Sec. 7, Range 2 west, Township 15, Choctaw Co.

It will be seen from the accompanying map that the masses were found in almost a straight line N. and S. and along a nine-mile stretch of the public road. As in the case of the Coahuila, Mexico, irons (J. Lawrence Smith), which were found in a line N.E. to S.W., the smaller pieces falling first, one cannot avoid applying such a theory to the present find. The main mass moving from north to south, parted during its flight and the fragments continued in the same general direction, the smaller ones falling first. In support of this theory are the facts: at the northernmost point of the line was found a mass of about $3\frac{1}{2}$ k.; three miles to the south, a mass of which only a portion ($\frac{3}{4}$ k.) was preserved; one mile south of that, a $3\frac{1}{4}$ k. piece; four miles farther south, two were found $\frac{1}{4}$ mile apart, weighing respectively 12 k. and 9 k.; finally one mile beyond, at the south end of the line, the largest, weighing about 15 k. In all probability, the decrease in weight, due to exposure after reaching the earth, was relatively about the same for each. Since the fall occurred in two counties, near three small villages, it may be conveniently designated by the name of the nearest geographical feature, the "*Tombigbee River*," in the western watershed of which the find was made.

The two other iron meteorites, which are near enough geographically to the "*Tombigbee River*" to suggest relationship, are "*Claiborne*," about 60 miles to the S.E. in Clarke Co., Ala., and "*Oktibbeha Co.*," about 60 miles west in Mississippi. That they are not of the same fall is shown by their widely dissimilar compositions, the first containing 95.02 per cent iron and 4.11 per cent nickel; the second, 66.56 per cent iron and 24.74 per cent nickel; the third, 37.69 per cent iron and 59.69 per cent nickel.

Philadelphia, July 10, 1899.

ART. XVII.—*On the Orthoclase Crystals from Shinano, Japan*; by C. IWASAKI, Kyoto, Japan.

THE crystals of orthoclase described in this paper were obtained by me from Mr. K. Okubo, a schoolmaster in Nozawa, Minamisakugōri, Shinano, who has had the kindness to place in my hands some fifty specimens from a locality recently discovered by him in Mōrai-yama of the same district.

In the western margin of the geological block known as the Chichibu region, where the geology of the Japanese Paleozoic formation has been studied and the name "Chichibu Group" has been given, there are several occurrences of quartz-diorite as dikes. Through some of them, there are mineral veins a foot in width formed, and the orthoclase crystals are found in them mixed with quartz.

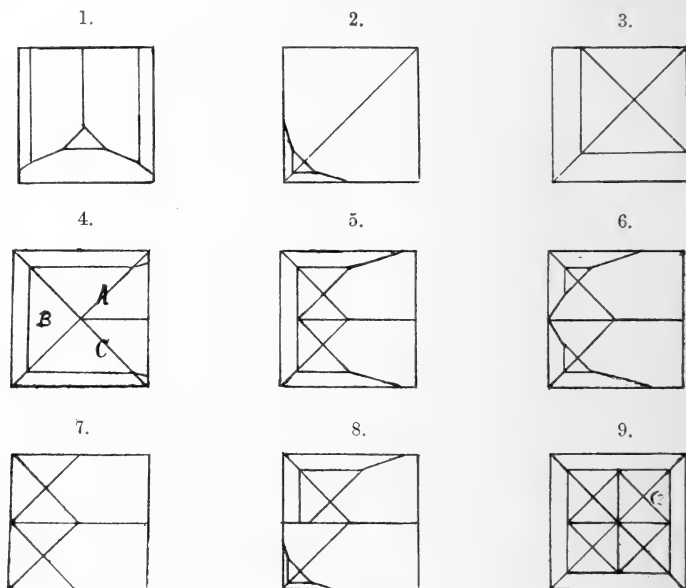
The orthoclase crystals are all elongated in the direction of the clino-axis; one end being always broken. They are of moderate size, and measure one and a half inches in the longest diameter. They are brownish white in color, often with thin coating of the brown earth. The clinopinacoid (010) is comparatively clean and lustrous, and striations parallel to the vertical axis are seen on it. The basal face (001) is usually discolored and the cleavage along it is most perfect. All faces are so dull that the facial angles can only be measured approximately by the contact goniometer. Six crystal faces, (010), (001), (110), (130), ($\bar{1}01$), ($\bar{2}01$), have been identified.

The crystals are nearly always twinned after the Baveno type but of different types. They may be divided into the four classes mentioned below.

(1) *Simple crystals* (fig. 1).—The simple crystals are most rarely met with. Only two were found among fifty specimens, and, even in them, the twinning traces are seen in their margin. The crystal habitus is as usual.

(2) *Twin crystals of the Baveno type* (figs. 2 and 3).—All crystals are drawn in the orthographic projection toward the clino axis. Fig. 1. Simple crystal; figs. 2, 3, twin crystals of the Baveno type (110) and (130) are more developed in 3. Figs. 4–8, Baveno trillings: 4, normal case; in 5 and 6, the groove between A and C, proceeds into B; in 7 the prism is absent; in 8, the faces are unequally developed on both sides of the groove. Fig. 9. Baveno fourling. The simple crystals are frequently twinned after the Baveno type, a diagonally truncated prism being the result. Among the terminal faces (110) plays the most important rôle, ($\bar{1}01$), ($\bar{2}01$) and sometimes (130) being only seen in a corner or on the edges, but rarely ($\bar{1}01$) and ($\bar{2}01$) are highly developed and (110) is depressed in one side as shown in fig. 3.

III. *Baveno Trillings*.—The crystals are most frequently twinned after the Baveno type in the cyclical order, and form the same individual as so-called "Drilling" of Naumann.* If these three individuals be noted as A, B, and C (fig. 4), the prismatic faces of A and C are in juxtaposition forming a groove between these two faces. The most simple case of this type is shown



in fig. 4. Often the groove proceeds into B, and two faces of the prism of the same individuals make a reëntrant angle ($\bar{2}01$) sometimes ($\bar{1}01$) being divided into two areas. The development of the crystal faces on both sides of the groove commonly takes place to the same extent. But sometimes they are unequal as shown in fig. 8.

IV. *Baveno Fourling* (fig. 9).—Finally four crystals are twinned in the cyclical order, forming the so-called "Vierling" of Naumann, eight faces of the prism of the four individuals meeting each other, forming the adjacent faces, and at the same time making a hollow pit in the center of the top of the longer diameter of the crystal. The four faces parallel, the longer diameter consists of four basal faces, while the clinopinacoids are wholly hidden. Hessenberg† describes such crystals from Orfano of Italy. The orthoclase here described is simpler than his, and does not form the "4 tower in the four corners" described by him, but only the hollow pit in the center.

* Hintze, *Handbuch der Mineralogie*, ii, 1341.

† *Min. Not.*, 1867, iv, 45, 183, v, 15.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the two new Radio-actino Elements, Polonium and Radium.*—Early in 1898* Mme. SKŁODOWSKA CURIE pointed out the fact that certain uranium and thorium minerals, pitchblende, torbernite and autunite, emitted Becquerel rays more actively than even uranium or thorium, and suggested the presence in these minerals of a new substance. Later, in conjunction with her husband, P. CURIE, she published the method followed in the chemical examination of pitchblende, which resulted in the isolation of the new active substance. The mineral was dissolved in acid and the solution treated with hydrogen sulphide. The uranium and thorium remained in solution and the precipitate contained, besides lead, bismuth, copper, arsenic and antimony, the sulphide of the new material, which being insoluble in ammonium sulphide, was thus separated from arsenic and antimony. The insoluble sulphides were treated with nitric acid, and a partial separation from lead effected by sulphuric acid. On exhausting the lead sulphate with dilute sulphuric acid, the active substance together with copper and bismuth were obtained in solution. On adding ammonia, the new body and the bismuth were thrown down, thus separating them from copper. Complete separation from bismuth was not obtained; though by heating the mixed sulphides to 700°, the greater volatility of the new sulphide enabled them to get a product which was 400 times more active than uranium. Believing this new substance, resembling bismuth so closely, to contain a new element, the authors gave it the name *polonium* from Poland, Mme. Curie's native country. For this discovery the Academy of Sciences awarded the Gegner prize to Mme. Curie.

In continuing their observations upon pitchblende, M. and Mme. CURIE, in association with BEMONT, detected a second radio-active substance in this mineral, having entirely different chemical properties. It resembles barium closely, not being precipitated either by hydrogen sulphide, by ammonium sulphide or by ammonia. Its sulphate is insoluble in water and in acids, its carbonate is insoluble in water and its chloride, while very soluble in water, is insoluble in concentrated hydrogen chloride and in alcohol. The product obtained gave the barium spectrum, showing that the body consisted mainly of this substance. But barium is not radio-active; and since radio-activity seems to be an atomic property, the authors attribute it to a new element associated with the barium. The first portions obtained were 60 times more active than uranium. By a series of fractional precipitations of the chloride with alcohol a final product was obtained 900 times

* C. R., cxxvi, 1101-1103.

more active. The spectrum examined by Demarçay gave a characteristic line of wave-length 3814·8. In consequence the authors propose for the new element the name *radium*. Like uranium and thorium, polonium and radium act photographically on sensitive plates and render the surrounding air a conductor of electricity; though they are far more effective. An exposure of half a minute gives with the latter an effect equal to that of several hours with the former.—*C. R.*, cxxvii, 175–178, July, 1898; 1215–1217, 1218, December, 1898.

G. F. B.

2. *On Liquid Hydrogen*.—The Centenary of the Royal Institution of Great Britain was fittingly celebrated on the 7th of June by an admirable lecture, by Professor DEWAR, on Liquid Hydrogen as an instrument of research. He had upon the lecture table a liter of this substance, preserved in triple vessels containing liquid air surrounding the hydrogen. It is transparent and has a well-defined meniscus; and when the cotton plug closing the tube is removed, the entering air is at once frozen to a solid and falls to the bottom like a precipitate. A small wad of cotton on a glass rod dipped into it and lighted gives the well-known hydrogen flame. A small cork ball sinks at once in liquid hydrogen. A solid immersed in it for a few seconds becomes so cold that it liquefies the surrounding air on withdrawal, which runs off in drops; while a tube of liquid air is at once solidified in it. An empty bulb placed in the space above the liquid hydrogen is at once filled with solid air. Oxygen also becomes solid and when lifted out is seen gradually to melt. Though not itself magnetic the oxygen liquified from the air on a cotton plug cooled in hydrogen is drawn to the magnet. The real temperature of the liquid hydrogen he had found to be 21° absolute, a hydrogen gas thermometer and a german-silver resistance thermometer giving the same reading. Very perfect vacua were obtained by cooling tubes containing air in liquid hydrogen; so perfect indeed that no electric discharge could pass through them. Comparative contraction of a hydrogen thermometer placed in liquid air and in liquid hydrogen showed that in the latter was four times as great as in the former. To reach the absolute zero even approximately two more steps must be made substantially as great as the one now made between liquid nitrogen and liquid hydrogen.

3. *On Ozomolybdates*.—By digesting a molybdate of one of the alkali metals with hydrogen peroxide, MUTHMANN and NAGEL have found it possible to add oxygen to it to the extent of one atom of oxygen or less per atom of molybdenum. The compounds thus formed, however, cannot properly be regarded as salts of permolybdic acid, since they lose oxygen readily, reducing silver oxide and permanganic acid with evolution of oxygen. The apparent addition of an atom of oxygen therefore seems really to be a replacement of one atom of oxygen by two linked together as in hydrogen peroxide or ozone. Hence the name ozomolybdates given by the authors to this class of compounds.

Ozomolybdic acid, $\text{H}_2\text{MoO}_6 \cdot (\text{H}_2\text{O})_x$ ($x = 1\frac{1}{2}$?) was obtained by digesting molybdic oxide with a 25 per cent solution of hydrogen peroxide, finally on the water bath, filtering and concentrating the filtrate under reduced pressure. It is amorphous, and orange-red in color; and besides reducing permanganate, silver oxide and hypochlorites, it liberates the halogens from their hydrogen compounds. Rubidium and caesium ozomolybdates, prepared similarly, are described. They are crystallized and vary in color from yellow through yellowish red to orange-red.—*Ber. Chem. Ges.*, xxxi, 1836–1844, July, 1898. G. F. B.

4. *On the Action of Charcoal in the Purification of Spirit.*—An exhaustive investigation has been made by GLASENAPP as to the part which charcoal plays in the purification of spirit. From the results obtained it appears that charcoal does not absorb fusel oil but acts chemically through the oxygen condensed in its pores. The fusel oil is oxidized to ketones and aldehydes and the latter partly to acids, which then to some extent act on the alcohols forming esters with them, these various products giving a characteristic odor and taste. Since these bodies are soluble in chloroform, they would, unless previously removed, be counted as fusel oil in applying Rose's well known process of analysis. Charcoal itself absorbs these products to a large extent; so that in fact spirit filtered through it often shows less aldehydes than the unfiltered sample. On heating the charcoal afterward to regenerate it, a distillate is obtained which is rich in ethers and aldehydes, though it does not contain more fusel oil than the original liquor. The author advises thoroughly impregnating the charcoal with oxygen by heating the regenerated material in a current of dry air. He suggests that by filtering at a somewhat higher temperature, a better product might be obtained.—*Zeitschr. angew. Chem.*, 617–621, 1898; *J. Chem. Soc.*, lxxiv, 616, December, 1898. G. F. B.

5. *On the Constitution of the Simplest Proteids.*—According to the earlier experiments of KOSSEL, the molecule of the complicated proteids contains an atom-complex similar to the protamine group. Hence more accurate chemical knowledge of the protamines should give us an insight into the constitution of the albumin molecule. The author has therefore studied more carefully the three following protamines: Sturine from the spermatozoa of the sturgeon, salmine from that of the salmon, and clupeine from herring sperm. The protamine sulphates were prepared according to a method already described, and freed from the last traces of nucleic acid. On adding alcohol to the evaporated solution, the protamine sulphate separates. Clupeine sulphate dried at 110° – 120° has the formula $\text{C}_{80}\text{H}_{57}\text{N}_{17}\text{O}_6(\text{H}_2\text{SO}_4)_2$. It is a white powder, easily soluble in warm water. On cooling the solution a colorless highly refractive oil separates, which like the clupeine sulphate itself is lævo-rotatory. Clupeine has a strongly alkaline reaction. Salmine sulphate probably has the formula $\text{C}_{80}\text{H}_{59}\text{N}_{17}\text{O}_7(\text{H}_2\text{SO}_4)_2$, and differs from clupeine sulphate only in

having H_2O more ; a difference which the author attributes to the mode of drying. As they have the same solubility, optical activity and refractive index, they are probably identical. Sturine is more soluble than the others, and its sulphate, which is an oil, has the probable formula $(\text{C}_{36}\text{H}_{69}\text{N}_{19}\text{O}_7)_4 \cdot (\text{H}_2\text{SO}_4)_{11}$. By hydrolysis, protones or peptones of the protamines are first produced. Then the hexon bases appear, histidine, arginine and lysine. Clupeine gives a molecule each of histidine and lysine and three of arginine, while the sturine gives one molecule of histidine, two of lysine and three of arginine. Since proteids as well as protomines yield these hexon bases, it is reasonable to suppose that the albumin molecule contains a protamine complex. To this are attached other groups which yield the amido acids of the fatty series, a third group gives tyrosine, and a fourth the decomposition products containing sulphur.—*Zeitschr. physiol. Chem.* xxv, 165–189, 1898. G. F. B.

6. *On Hæmochromogen*.—Hæmochromogen has been prepared by VON ZEYNEK by reducing an ammoniacal alcoholic solution of hæmatin with hydrazine hydrate in an apparatus from which both oxygen and moisture could be excluded. From the solution it is precipitated by a mixture of alcohol and ether as a red amorphous mass resembling red phosphorus. As a mean of five analyses, the following numbers were obtained : C 63.83, H 5.66, Fe 9.25, N 11.48, O 9.78. Since the formula of hæmatin itself is doubtful, these numbers cannot lead to any definite conclusion as to the constitution of hæmochromogen. When its solution in ammonia is neutralized with acetic acid, a voluminous brownish-red precipitate is thrown down which contains iron, and on redissolving it in ammonia shows the characteristic spectrum of hæmochromogen. This substance appears to be the only product of the action of hydrazine hydrate on hæmatin ; while with oxyhæmoglobin and methæmoglobin the action goes farther, producing hæmoglobin, then hæmochromogen ; the solution becoming soon decolorized.—*Zeitschr. Physiol. Chem.*, xxv, 492–506, 1898. G. F. B.

7. *Geschichte der Physikalischen Experimentierkunst*. Von Dr. E. GERLAND und Dr. F. TRAUMÜLLER ; pp. 442. Leipzig, 1899. (Wilhelm Engelmann.)—This volume occupies quite a new field. There have been histories of physics which have given an account of the development of physical laws and principles, but here we have the course of experiment detailed from the earliest time down to the first half of the present century. Some of the opening pages are given to the Egyptians and their work in metallurgy, and then follows an account of the discoveries of the Greeks and Romans, the Byzantines and Arabians until we reach the scientific awakening of the sixteenth century. From here on, one familiar subject after another is developed, and it is highly interesting to see how many experiments and illustrations which still live in modern text-books had their origin several hundred years ago. The figures introduced are numerous and well chosen

from the original sources and add much to the general interest of the volume, even when not absolutely necessary for the explanation of the subject. We have, for example, the frog's legs of Galvani's classical experiment; the Magdeburg hemispheres, with the experimenter at work, and again with the horses attached attempting to pull them apart, and many others.

II. GEOLOGY AND MINERALOGY.

1. *The Terminology of Vertebral Centra*; by G. R. WIELAND (communicated).—In the early nomenclature of palæontology vertebræ received no definite names based on the termination of their centra in flat, concave, convex, or saddle-shaped surfaces. Instead descriptive sentences were used. Thus, Cuvier states that the centra of crocodilian vertebræ are "*concave en avant et convex au derrière.*"

Later, Owen applied to the principal types of centra the names now in common use. It may be said of these terms that they are expressive and euphonious, but do not form a connected system, though this is suggested by the correspondence between lenses and the types of centra.

In the following table an attempt is made to unify Owen's names, and extend them into a completed system :

Vertebræ.				
LENSES.	OWEN.	SYSTEMATIZED.	DERIVATION.	EXAMPLES.
(Plane)	Amphiplatyan	Platyan	Gr. <i>πλατύς</i> , flat	<i>Plesiosaurs.</i>
Biconvex	Biconvex	Cyrtean	Gr. <i>κυρτός</i> , convex	{ First caudal of Sauropodous Dinosaurs.
Biconcave	Amphicælian	Cælian	Gr. <i>κοίλος</i> , concavity	<i>Ichthyosaurs.</i>
Plano-convex	-----	{ Platycyrtean Cyrtoplatyan	{ <i>ad seriatim.</i>	{ <i>Cardiodon.</i> First sacral of ex- isting <i>Crocodylia.</i>
Plano-concave	Platycælian	Platycælian		
Concave-plane	-----	Cæloplatyan	"	<i>Pythonomorphs.</i> <i>Streptospondylus.</i>
Concavo-convex	Proccælian	Cælocyrtean	"	
Convexo-concave	Opisthocælian	Cyrtocælian	"	<i>Aves.</i>
(Saddle)	-----	{ Ephippic Platyphippic, etc., etc.	Gr. <i>ἐπίπιον</i> , saddle <i>ad seriatim.</i>	

The proposed changes in these adjectives require little further explanation. In describing a given centrum the anterior face is always taken first, and the centra further described adjectively when necessary, as at present. For example, the cervical vertebræ of *Chelydra serpentina* would be described as follows :—

The third cervical is cyrtocælian, the fourth cyrtean, the fifth and sixth are cælocyrtean, with the posterior, or cyrteal, face of the latter nearly flat and very broad; the seventh is platyan with

very broad faces, the hinder being slightly convex, while the eighth like the fifth and sixth is cœlocyrtæan, but differs from the others in the expansion of its neural spine and the arching backward of its postzygapophyses over the convex prezygapophyses of the first dorsal upon which the former play backward and forward. (Cf. Huxley's *Anatomy of Vertebrated Animals*, London, 1871, p. 171.)

2. *Cycadean Monœcism*; by G. R. WIELAND (communicated).—The living and fossil Cycads, so far as hitherto observed, are *diœcious*. Hence, it is important to note that certain Mesozoic species from the Black Hills, now in the Yale Museum, and referred to the genus *Cycadeoidea* as commonly employed, have been recently found to be *monœcious*. These possess essentially the types of male and female fructification described by the writer in his preliminary papers on a Study of American Fossil Cycads, Parts I-III (this Journal, March-May, 1899).

The species there recorded as *diœcious* are probably of that nature. All the evidence at present available strongly points to the *diœcism* of *Cycadeoidea Colei*, *C. turrita*, *C. Wielandi*, *C. ingens*, etc. On the contrary, other species in full fruit recently studied bear typical male and female fructifications on the same trunk. Of these may be mentioned *Cycadeoidea Minnekahtensis*, *C. Wellsi*, *C. Dacotensis*, etc. The limits of this *monœcism* and *diœcism* can not be determined without abundant material and a long series of observations. Fortunately, the richness of the Yale collection will go far towards solving this problem.

The condition of *monœcism* in Cycads thus places this group of plants one step nearer the conifers. Nevertheless, in view of the fact that the Cycads of the Black Hills Jurassic were so prolific in habit, it is not surprising that *monœcious* forms should occur, especially when the great variability of gymnosperms in this respect is considered. That these Mesozoic species, so closely related as to have been included in a single genus, should be found to possess both kinds of unisexuality, however, adds great interest to the *Cycadææ*, as well as an important chapter to the knowledge of sexual characters in plants.

3. *Sur Stereosternum tumidum, Cope*; by H. B. GEINITZ. Ann. Soc. géol. de Belg., xxv, 8 pages, and one large double-page plate, 1899.—Dr. Geinitz reproduces, by some photographic process, the forms of two fine specimens of this species obtained from the Permian beds of São Paulo (Brazil), and now in the Royal Museum of Mineralogy at Dresden. In the text, the formations and known fossil associates, as well as the biological characters of the specimens, are defined. Though believed to be Permian, the exact age of the beds is not established beyond controversy.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XVIII.—*On the Gas Thermometer at High Temperatures;*
by LUDWIG HOLBORN and ARTHUR L. DAY.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg,
Germany.]

THE high temperature measurements which have been undertaken by various observers with the gas thermometer are not yet free from considerable disagreements.

Violle* determined the melting point of gold to be 1035°C ., a value which he afterward increased to 1045° ; Barus's† determination for the U. S. Coast and Geological Survey was 1092° , and one of the authors of this paper has published with W. Wien‡ the value 1072° .

In all three cases the melting point was not directly determined with the gas thermometer. Violle ascertained first the specific heat of platinum with the gas thermometer and then by calorimetric methods the melting point of gold, while in the last two instances a thermo-element was compared with the gas thermometer, after which it was used for the actual melting point determination.

Neither the indirect method, nor the inherent experimental difficulties which stand in the way of all investigation at high temperatures, sufficiently explain the differences mentioned. Especially recently, the relative measurement of high temperatures electrically has become less difficult and more accurate, as a consequence of which the variations of the temperature scales of different observers among themselves is the more unpleasantly conspicuous and disturbing.

* Violle, C. R. lxxxix, 702, 1889.

† Barus, Bull. U. S. Geol. Survey, 54, 1889; Proc. Am. Acad., xxvii, 100, 1892.

‡ Holborn & Wien, Wied. Ann., xlvii, 107, 1892, and lvi, 360, 1895.

AM. JOUR. SCI.—FOURTH SERIES, VOL. VIII, No. 45.—SEPTEMBER, 1899.

With the idea that these differences were, in part at least, due to the construction and handling of the gas thermometer itself, the first step toward the establishment of a new scale was thought to lie in the direction of an investigation of the principal instrument involved. The results of such an investigation are contained in this paper.

There is no doubt that the principal difficulty lies immediately at hand, viz., in providing a suitable bulb to hold the expanding gas. Since Deville and Troost* proved that hydrogen would pass through the walls of a platinum bulb at high temperatures, observers in general have turned to porcelain as the only practicable material, although the results obtained by Becquerel† with the Pouillet platinum bulbs compare by no means so unfavorably with the determinations above quoted, and the discrepancy between the Becquerel values and those obtained at about the same time by Deville and Troost was sufficiently explained by the dissociation of the gas (iodine vapor) chosen for the observations.

Among recent observers Violle, following the precedent of Deville and Troost, used porcelain bulbs glazed inside and out, while Barus, as well as Holborn and Wien, adopted those glazed only on the outside. The limits of usefulness of the bulbs with inside glazing must be reached when the glaze begins to melt, i. e. at about 1100° , otherwise vaporization is certainly to be feared. The porcelain walls themselves hold out longer, in fact the bulbs without inside glazing used by Holborn and Wien were used up to 1450° , but of course at such a temperature the pressure inside and out must be approximately the same, that the already soft walls may not be deformed thereby. At these temperatures porcelain bulbs only remain air-tight by virtue of the glazing—unglazed porcelain is not air-tight.

Brief review of investigation.—Our experiments up to a temperature of 550° were made with bulbs of Jena "borosilicate" glass No. 59^m and hydrogen as the expanding gas; then porcelain bulbs glazed inside and out were tried up to 1100° , first with hydrogen and afterwards with atmospheric nitrogen; next porcelain bulbs with outside glazing only were heated above 1200° with nitrogen; and finally a platin-iridium bulb, which when heated electrically proved entirely free from the disadvantages of porcelain, was used with chemically pure nitrogen over the whole range of temperature up to 1300° .

Toward the close of the observations we also had the advantage of entirely new manometric apparatus especially adapted to our purposes, in which the volume of unheated gas was much reduced and the use of low pressures in the bulb made possible.

* Deville and Troost, C. R., lvi, 977, 1863.

† E. Becquerel, Ann. de Chim. et de Phys., III, lxxviii, 49, 1862.

The glass bulb proved to be exceedingly well adapted to the purpose up to 500° , showing no appreciable change in the zero point after being repeatedly heated, while with porcelain, even when nitrogen was afterward substituted for the hydrogen, the zero point did not remain constant, but rose slightly after each heating, denoting an *increase* in the gas pressure. Furthermore, the expansion-coefficient of the gas between 0° and 100° often showed changes larger than could be accounted for by the errors in observation.

Such changes, even when they remain small and the temperatures measured with the bulbs agree fairly among themselves, are persistent and disturbing factors in the measurement of high temperatures.

Another misfortune arises from the fact that porcelain is not a definite chemical compound, and bulbs from different sources may behave quite differently; even bulbs ordered at different times from the same source have the same unfortunate tendency.

These, with the above mentioned fact that bulbs glazed on the inside do not admit of use above 1100° at all, and the unglazed ones only with difficulty and under conditions of greatly diminished sensitiveness, led us to direct our attention once more to metallic bulbs and to investigate the behavior of a platinum-iridium cylinder under the above conditions.

From the results thus far obtained we do not hesitate to say that in our opinion such a bulb is certainly to be preferred to porcelain for the higher temperatures.

This bulb filled with nitrogen and heated to 1300° showed a constancy of the zero point and coefficient of gas expansion such as we have only been able to obtain from glass bulbs at comparatively low temperatures. This result is, however, in no small degree dependent upon arrangements for heating by electricity and the consequent freedom from all sorts of combustion products, which if present, as we observed repeatedly, pass rapidly through the bulb wall, even against an excess pressure within.

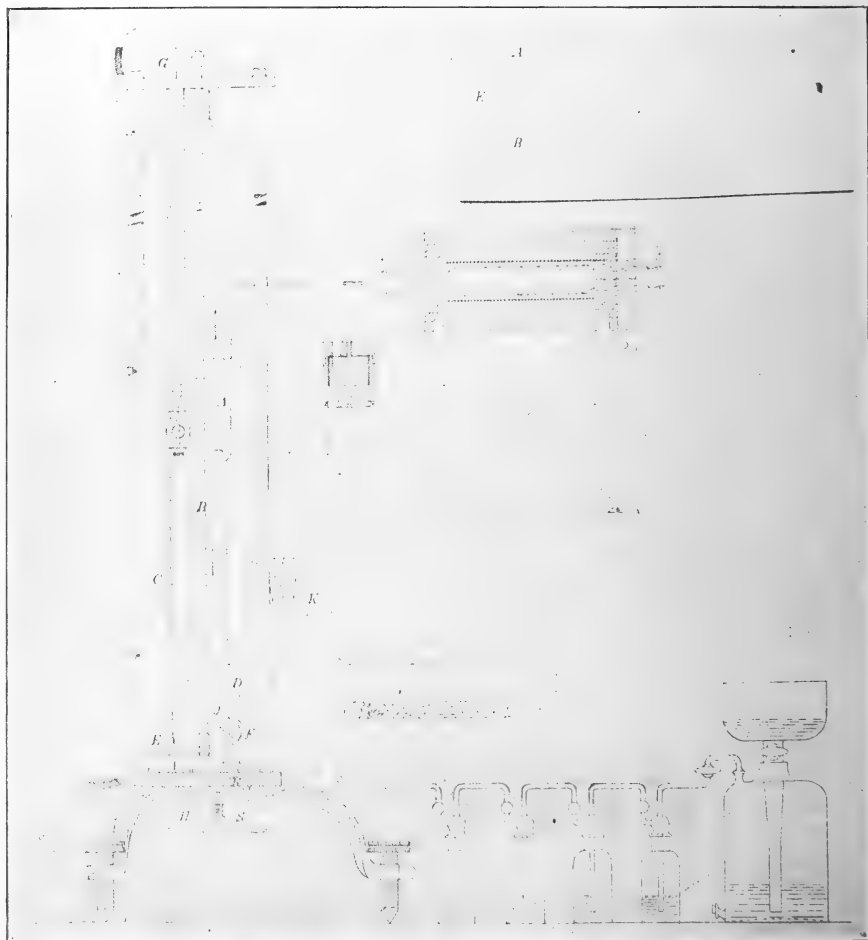
For comparison of the gas-thermometer readings among themselves, they were referred to a platinum, platinum-rhodium thermo-element observed simultaneously.

For temperatures up to 750° bulb and thermo-element were dipped into a bath of nitre and in the vicinity of 900° a zinc vapor bath was tried. As no bath is yet available for temperatures above that point which does not seriously injure the walls of the bulb, the remaining temperatures were attained electrically by heating a coil of nickel wire wound upon a thin tube of porcelain or clay. The last proved the most convenient of all both for producing and maintaining constant any temperature within the range of the present series.

1. Gas Thermometer.

For the experiments with the gas thermometer the "constant volume" principle only was used, in order that a nearly uniform sensitiveness might be maintained throughout the

1



entire range of temperatures. As manometer we had at first at our disposal an apparatus constructed by Fuess (Berlin) and used and described by Wiebe and Böttcher,* a few necessary changes being made to adapt it to our purposes. Afterward a second similar instrument from the same workshop was used, a drawing of which (fig. 1) is here given.

* Wiebe and Böttcher, *Zeitschr. für Instr.*, x, 18, 1890.

The manometer consists of two upright tubes, A and B, which dip into a closed iron reservoir, R, from which mercury may be drawn off through the steel cock, D, and let in from a storage reservoir, G, at the top, by way of the tube, C, and a second steel cock, E. Small changes in the height of the mercury column such as were necessary in the final adjustment for reading may be effected by means of the powerful screw, S, working upon a thin sheet-steel plate which forms the bottom of the reservoir.

The shorter tube is 80^{cm} long up to the metallic point where the adjustment to constant volume is made, for in order to avoid pressures much too great for the strength of the bulb at high temperatures, the pressure at 0° must be chosen small.

The adjustment to constant volume was made in the older instrument at the end of the platinum capillary which constituted the connection between the manometer and the bulb, and which was melted directly into the top of the shorter tube (corresponding to A). This arrangement, which we at first retained, left the "unheated space" unnecessarily large, which for our purpose was a decided disadvantage. The influence of this "unheated space" (the space between the surface of the mercury in the manometer and the bulb, filled with gas like the bulb but not heated with it) upon the resulting temperature increases much more rapidly than the temperature itself. We have consequently since then adopted the arrangement of Chappuis* and closed the short tube (A) by a carefully fitted metallic cap with polished under surface. This cap was fastened upon the tube with sealing wax and carried near the middle, where the capillary tube opened into the glass tube, a metallic point 0.4^{mm} long to which the mercury column is brought at each reading. In this way the space above the meniscus was reduced from 2^{ccm} to 0.4^{ccm} in a tube of 2^{cm} diameter. The metal point, intentionally rounded off in order to allow of more accurate setting, was made of nickel, as was also the entire cap, in order that it might not become amalgamated by contact with the mercury.

On the upper side this cap was hollow and was originally intended to contain mercury; at the last, however, we preferred to fit into the space a massive block of copper bored with a cylindrical hole to admit the bulb of a mercury thermometer. In this way the temperature of the space above the mercury column (A) is more accurately determined than if the thermometer were hung at the side.

We had, to be sure, in the old instrument a thermo-element within this space itself, the wires being passed in through the

*Chappuis, Trav. et Mém. du Bureau internat., vi, 28, 1888.

glass; the observations made with it also gave good results but the arrangement was inconvenient and awkward. At a distance of 161.61^{mm} below the nickel point, the tube contained a second point of colored glass projecting out from the wall of the tube itself, for purposes of volumetric measurement. The volume included between the points was 50.723^{ccm}.

The longer tube (B) was 2^m long and its inside diameter 12^{mm}. Its upper end is connected by means of a ground glass joint and a metallic return tube with a wash bottle containing phosphoric pentoxide, thereby assuring dry air above the mercury column.

To change the gas in the bulb a water aspirator could be attached to the wash bottle to secure the diminished pressure necessary for drawing the mercury from the shorter tube (A) when the pressure in the bulb was low. When the mercury is thus drawn below the three-way cock, J, this may be turned and connection made through a second similar cock, K, either with the mercury pump or the gasometer and drying tubes. All connections were made with glass or sealing wax and tested from time to time to see that they were and remained absolutely air-tight. Rubber connections were conscientiously avoided.

The temperature of the mercury in the manometer was determined by the thermometer fitted into the cap above described and three other similar ones, whose bulbs dipped into short tubes containing mercury placed directly beside the long manometer tube at proper intervals and giving the temperature at the corresponding height in the long tube with sufficient accuracy.

The oven being always in a separate room, the changes of temperature about the manometer were very small and the time between observations necessary for regulating the oven temperature to the required degree of constancy, always sufficient to enable the thermometers to indicate any small changes which may have existed.

When mercury was let into the apparatus from the reservoir (G) at the top, more or less air bubbles always came with it, which collected in the main reservoir (R), having no means of escape. To avoid this in the new instrument, a short tube, D, with a glass cock, F, was introduced into R at its highest point, while the manometer tubes extended much deeper, thereby allowing the air to be drawn off at any time without endangering the gas in the bulb—a matter of the highest importance.

The manometer scale was ruled in millimeters for a length of 1.87^m, and carried upon a slider the knife-edge and a micrometer screw and vernier reading intervals of 0.02^{mm} directly. The largest scale error amounted to 0.04^{mm}.

The platinum capillary tube serving to connect the bulb with the manometer was soldered at one end into the metallic cap before mentioned and at the other attached to the stem of the bulb with sealing wax, this arrangement proving quite as trustworthy and convenient as a soldered joint. The sealing wax could be kept cool with water if necessary. The length of the capillary tube was much reduced in the new instrument (from 1.37^m to 0.85^m), an improvement rendered possible by the electrical oven, which could of course be much better protected from radiation than a gas heater. Under the new arrangement a glass partition was amply sufficient to separate oven and manometer, a service for which before a brick wall had been deemed necessary. That the gas pressure in bulb and manometer may come quickly to a condition of equilibrium, the capillary tube should not be chosen less than two-thirds of a millimeter in diameter.

This flexible capillary also enabled us to move the thermometer bulb about at will for determining ice and boiling points after each heating; we found it, however, better to move it as little as possible, and in our later experiments the oven was mounted upon a framework provided with wheels and moving upon a track which enabled it to be pushed aside when the bulb was taken out, and ice and boiling point observations to be made at the same point by appropriately constructed apparatus. By this arrangement the amount of bending of the capillary required was very small.

Ice and boiling point observations were made after each heating during these experiments, not so much for their value as constants of the instrument and for the temperature determination as to determine any change which the measuring gas might have undergone at the higher temperatures.

The temperature as observed with the air thermometer was calculated according to the following formula:

$$H_0 \left(1 + \frac{v_i}{V_0} \cdot \frac{1}{1 + at_i} \right) = \frac{H}{1 + at} \left(1 + 3\beta t + \frac{v_i}{V_0} \cdot \frac{1 + at}{1 + at_i'} \right)$$

where

H_0 = Pressure at 0°.

H = " " t° .

V_0 = Volume of bulb at 0°.

v_i = " " "unheated space" at the temperature of the room. (Changes in volume v_i due to temperature neglected.)

t_i and t_i' = temperatures of "unheated space" with bulb in ice and at temperature t .

a = coefficient of expansion (technically *pressure coefficient or coefficient of expansion at constant volume*) of the gas between 0° and 100° (determined after each heating).

3β = cubical coefficient of expansion of the bulb.

The left side of the equation is a constant quantity for each filling if the zero point remains constant.

For the various bulbs used the values of V_0 and v_1 are quite different; the value in each case is therefore especially stated, and the percentage of effect which the "unheated space" has on the resulting t .

2. Electrical Measurement.

The measurement of the electromotive force of the thermo-elements was made by the "compensation" method. Cadmium cells served as standards of potential-difference.

The cold junctions of the thermo-elements were contained in glass tubes surrounded by melting ice.

A Siemens and Halske voltmeter was of great service in the regulation of the temperature of the oven.

3. Experiments with glass bulb.

A bulb of Jena glass No. 59^{III} was used for the measurements between 200° and 500°. The gas was hydrogen, chosen chiefly in order to see whether this gas, whose expansion is made the basis of modern thermometry, can be advantageously used in practice above 200°.

In these lower temperatures the thermo-elements do not form a good basis of comparison for the air thermometer; it is, however, perfectly possible to detect any change which the gas may have undergone during the heating through changes in the ice point or coefficient of expansion.

Dimensions of Bulb.—The glass bulb had the form of a cylinder with rounded ends, 16^{cm} long and 3.5^{mm} outside diameter. The stem was 40.0^{cm} long, 0.75^{mm} in inside diameter, and bent to a right angle nearly in the middle.

The volume as measured at the beginning was 166.53^{ccm}, and at the end 166.43^{ccm}, the determination being made by filling with distilled water and weighing. The bulb had already been seasoned by repeated heatings to 500° before the first determination was made.

Unheated Space.—The temperature of the stem, as well as of the platinum manometer capillary, was determined by mercury thermometers placed at intervals close by and from whose readings an integral temperature of the unheated space, in this case amounting to 2.701^{ccm}, was obtained. This value is the result of a volumetric determination made at the beginning of the experiments. A determination by weighing with water at the close gave 2.668^{ccm}.

Heating arrangements.—For all the observations with the glass bulb a nitre bath was used, heated by Bunsen burners. The bath was contained in a cast iron kettle 34^{cm} high and 18^{cm} in diameter, provided with a cover through which the thermometer bulb and the porcelain tubes containing the thermoelement were passed, the whole being protected from radiation by a thick outer cylinder of fire-clay. The bath was stirred continually by a turbine wheel driven from outside. Inasmuch as the bath when cold solidified, the kettle was first heated to 250° empty and the previously melted nitre poured in through a funnel. At the close of the day's measurements the nitre was drawn off while still hot with a siphon.

Hydrogen.—The hydrogen used was generated electrolytically from dilute sulphuric acid, and before being admitted into the bulb was passed through two wash bottles containing alkaline solution of pyrogallie acid to remove traces of oxygen present, and drying tubes containing calcium chloride and phosphoric pentoxide. Failure to take this precaution always resulted in a fall of the ice point after heating, amounting to from 3 to 5^{mm} mercury pressure. This difference diminished with subsequent heatings (the heatings were each about five hours long), as may be seen in the following instance:

				Gas pressure at 0·0°.
Bulb freshly filled				567·80 ^{mm} Hg.
After 1st heating (to 510°)				564·63 “
“	2d	“	“ 530	564·15 “
“	3d	“	“ 500	563·61 “
“	4th	“	“ 540	562·83 “
“	5th	“	“ 540	562·56 “

The phenomenon is to be attributed to a gradual combining of the hydrogen with the oxygen present and occurs even when the temperature is not carried above 400°. Before the final filling the bulb was always evacuated at a temperature of 500° and allowed to stand for several hours, being “rinsed” from time to time with dry hydrogen. The generating apparatus and connections were perfectly air-tight and remained so throughout.

Expansion of Bulb.—For the glass bulb 3β is assumed equal to 0·000018,* a value determined for the temperature range 0°–100°. The “unheated space” affects the result (*t*) 2·6 per cent at 200° and 4·1 per cent at 500°.

*Thiesen, Scheel, and Sell, *Wissensch. Abhandl. d. Phys.-Tech. Reichsanstalt*, ii, 129, 1895.

TABLE I.

Bulb (No. 1).—Jena glass No. 59^m. Gas—Hydrogen. $V_0 = 166.38^{\text{ccm}}$, $v_1 = 2.701$, $3\beta = 0.000018$.

After filling.	H_0	a	t	e_1	Obs.—Calcul.
1st day	597.17	0.003657			
2d "	597.18	0.003658			
4th "			397.1°	3072	—0.3°
			393.1	3043	—1.2
			444.2	3485	—0.2
			518.4	4230	—0.8
5th "	597.17	0.003661			
6th "			342.4	2573	—0.7
			396.1	3073	—1.4
			458.1	3647	—0.5
			458.1	3656	—1.2
			487.3	3930	—0.8
7th "	597.19	0.003661			
Bulb freshly filled.					
1st day	638.87	0.003656			
2d "			309.3	2275	—0.7
			365.8	2787	—0.8
			406.8	3156	+0.8
			406.3	3158	—0.3
			462.1	3691	—1.0
			510.0	4147	—0.6
3d "	638.86	0.003656			
6th "			332.0	2470	+0.3
			371.9	2835	+0.1
			407.2	3163	0.0
			452.2	3586	+0.1
			502.5	4071	+0.3
7th "	638.72	0.003656			
8th "			311.4	2286	+0.2
			350.6	2640	+0.1
			405.5	3145	+0.3
			460.2	3653	+1.0
9th "	638.72	0.003655			
10th "			251.4	1763	+0.1
			250.7	1757	+0.1
			302.4	2201	+0.7
			413.8	3219	+0.7
			465.5	3708	+0.6
			510.7	4144	+0.4
11th "	638.67	0.003654			
15th "			234.8	1624	0.0
			254.2	1783	+0.6
			275.5	1967	+0.5
			551.3	4546	—0.2
			529.4	4322	+0.7
			514.7	4181	+0.5
16th "	638.26	0.003656			

Table I gives the results obtained from two separate hydrogen fillings between 200° and 500° . It contains the ice point (H_o), coefficient of expansion of the gas between 0° and 100° (α), the temperature as observed with the gas thermometer and calculated according to above formula (t), with the corresponding E. M. F. of the thermo-element T_1 in microvolts (e_1).

For this element a curve has been drawn based upon the mean of all the observations made with it between 200° and 1150° . Its form is given by the following table.

TABLE II.
Thermo-element T_1 .

	Microvolts.		Microvolts.
200°	1334	700°	6044
250 .	1752	750	6566
300	2186	800	7096
350	2635	850	7634
400	3096	900	8180
450	3566	950	8734
500	4044	1000	9296
550	4531	1050	9863
600	5027	1100	10434
650	5531	1150	11009

The last column of Table I ("Obs.—Calcul.") contains the difference between any particular observed temperature and the corresponding point of this curve in degrees. The mean value of this error for this set of observations amounts to $\pm 0.64^{\circ}$ and is to be charged rather to the thermo-element than to the gas thermometer.

The differences between the separate values of the zero point (H_o) and of the coefficient of expansion (α) are not greater with the first filling than the maximum error of observation, which in reading barometer and manometer might in unfavorable cases combine to amount to 0.05^{mm} . The ice point in the second series of observations showed a tendency to fall, the amount of which, if we may except the last heating when the temperature was forced up to 550° , was 0.14^{mm} (maximum).

4. Experiments with porcelain bulbs glazed inside and out.

Bulbs.—Temperatures above 500° were next measured with a bulb of this type. These bulbs, in a form adapted for this purpose, cannot, on account of the fine capillary tube, be glazed by simply dipping a finished bulb in the glazing solution and burning. Deville and Troost succeeded in glazing their bulbs on the inside, only by preparing bulb and capillary in separate pieces and melting them together in the oxy-hydrogen flame.

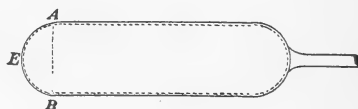
Inasmuch as the bulbs prepared in this way are often not air-tight, we have preferred to take the completely moulded though not burned bulb lacking only the end piece E (fig. 2), cover the inside with glazing solution, set the similarly smeared end piece on and burn the whole at once.

This gives of course on the inside an unglazed ridge some 2^{mm} wide and the same high where the cap is set on, but this has given no trouble.

To obtain a perfectly glazed outside surface (very essential) the bulbs must be hung up for burning by the stem, free from contact with each other or surrounding bodies. If it is desirable that the stem be curved for dipping in a bath, the finished stem may readily be bent in the oxy-hydrogen flame according to requirements.

The bulbs used by us were made in the "Königliche Porcellan-Manufactur" Berlin and have the form given in fig. 2.

2



The length was about 12^{cm}, diameter 3.7^{cm}, thickness of the walls 2^{mm} and the volume approximately 100^{cu cm}.

The length of the capillary stem was regulated according to our necessities, the original length being 60^{cm} and the diameter inside 0.85^{mm}. At the open end, it was bored out to a diameter of 2^{mm} to admit the end of the platinum capillary leading to the manometer; the joint was then made air-tight with sealing wax.

As coefficient of expansion the value obtained by Holborn and Wien for Berlin porcelain is adopted.

The "unheated space" with bulb No. II, mounted as here described, was 2.837^{ccm}. Effect on resulting t at 500°, 7.5 per cent; at 900°, 11.3 per cent.

Nitre Bath.—For a while the heating arrangements were retained as before, but above 500° the nitre bath decomposed more rapidly, in consequence of which it became strongly alkaline and its melting point sank; the outside glazing of the bulb was also considerably affected but remained air-tight throughout the observations.

The highest temperature attainable under these conditions is about 750°, but the mechanical arrangement for stirring could not be used above 600°. With an especially powerful heater and a smaller bath an attempt was made to carry obser-

vations still higher, but at about 810° a violent decomposition set in and in a few moments the entire bath had boiled away.

Hydrogen in porcelain bulbs.—At first one of these bulbs (No. II) was used filled with hydrogen, as in the case of the glass bulb; here, however, the bulb was evacuated at 700° instead of 500°, then rinsed as before with the dry gas. Table III contains two sets of results obtained under these conditions.

TABLE III.*

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Hydrogen.					
$V_0 = 101.136^{\text{ccm.}}$ $v_0 = 2.837^{\text{ccm.}}$ $3.3 = 0.0000132.$					
After heating.	H_0	a	t	e_1	Obs.—Calcul.
1st day	529.02				
1st " (2)	529.03				
2d "			309.3°	2258	+1.2°
			410.1	3179	+1.2
			527.6	4303	+0.8
			611.4	5119	+2.4
4th "	527.56				
4th "	527.58	0.003669			
5th "			407.9	3158	+1.3
			521.9	4234	+2.6
			601.8	5015	+3.0
			708.6	6100	+3.2
6th "	525.36	0.003672			
7th "			499.1	4018	+1.8
			609.6	5093	+3.0
			653.3	5527	+3.7
			729.3	6310	+3.7
8th "	522.48	0.003678			
Bulb freshly filled.					
1st day	532.03	0.003665			
3d "			536.6	4393	+0.7
			613.6	5142	+2.2
			677.6	5777	+3.5
			725.2	6269	+3.6
4th "	529.37	0.003675			

After each heating a considerable fall in the ice point (H_0) is noticeable and an increase in the coefficient of expansion of the gas. This seems to point to a chemical action at the higher temperatures between the hydrogen and the walls of the bulb and the generation of water vapor.

Nitrogen.—For the reason named, the use of hydrogen at high temperatures was abandoned and nitrogen substituted. This was obtained from atmospheric air by passing it through from four to six wash bottles filled with an alkaline solution of pyrogallie acid, thence after continuing on through

* Values of e printed in italics were not used in the determination of Tables II and X.

the usual drying tubes it was used as before, first for rinsing at 700° and then for the definite filling. Especial precautions were here taken to free the bulb from hydrogen, the evacuated bulb standing the entire day at 700°, the pump being operated at intervals. The drying tubes were also evacuated before the nitrogen was admitted. Table IV gives the values obtained with the same bulb (No. II) and nitrogen, the heating being done as before in the nitre bath.

TABLE IV.

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$V_0 = 101.136 \text{ cc.}$ $v_1 = 2.837$ $3\beta = 0.0000132$.

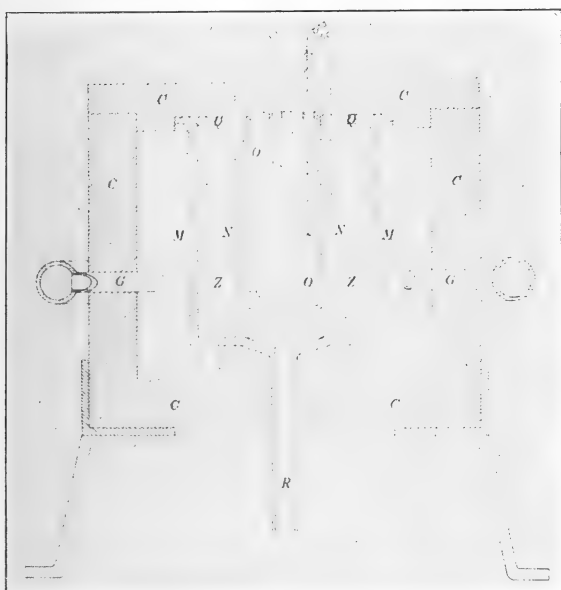
After filling.	H_0	a	t	e_1	Obs.—Calcul.
1st "	506.32	0.003677			
2d "			520.8°	4249	-0.4°
			606.3	5092	-0.2
			680.8	5844	+0.2
3d "	507.92	0.003681			
4th "			490.0	3942	+0.6
			573.7	4760	+0.5
			702.8	6050	+2.2
			706.9	6088	+2.7
6th "	508.54	0.003681			
Bulb freshly filled.					
1st day	432.87	0.003675			
3d "			280.4	2012	+0.3
			313.4	2301	+0.5
			512.3	4157	+0.6
4th "	432.62	0.003676			
6th "			506.0	4100	+0.2
			605.2	5087	-0.8
			633.8	5369	-0.2
7th "	432.41	0.003680			
8th "			612.2	5165	-1.6
			649.5	5537	-1.1
			690.9	5949	-0.1
			698.1	6015	+0.9
9th "	432.86	0.003680			
9th "			195.1	1295	-0.1
11th "			219.1	1488	+0.5
11th "			676.4	5789	+1.1
			673.9	5756	+1.8
14th "	433.09	0.003680			
15th "			576.7	4786	+0.9
			731.9	6366	+1.0
			735.1	6390	+1.9
16th "	433.61	0.003684			
Bulb freshly filled.					
1st day	417.29	0.003671			
2d "			813.1	7221	+1.4
			816.1	7253	+1.5

The first filling, in spite of the care exercised, still shows signs of the presence of hydrogen, afterward the changes in ice point and expansion coefficient become noticeably smaller, though the latter persists in a tendency to increase throughout.

The mean difference between the observed temperatures and those obtained from the curve (Table II) is $\pm 1.06^\circ$.

Zinc bath.—In order to continue these observations to a higher temperature an apparatus for boiling zinc was provided. The boiling kettle proper consisted of two concentric wrought iron cylinders, M and N (fig. 3), welded to a common bottom.

3



The ring-shaped space, Z, was filled with zinc while the inner cylinder, N, contained the bulb of the gas thermometer and the thermo-element, the latter protected as before by a porcelain tube. The whole was closed by a carefully fitted iron cover protected as much as possible by asbestos and fire-clay against loss of heat by conduction, and surrounded by a jacket of fire-clay pierced by a tube at the bottom where the zinc vapor passed off and the six blowpipes furnishing the heat. The latter were arranged in a spiral and directed tangentially against the zinc kettle.

It was unfortunately not possible to place the thermometer bulb and thermo-element directly in the zinc vapor on account

of the difficulty in packing them so as to prevent the vapor from escaping, consequently they were enclosed in a sheet iron cylinder made fast to the cover of the kettle. Around the outside of this cylinder the vapor circulated freely and took fire on coming in contact with the air at the end of the tube R.

Table V contains the results of two trials with bulb No. II in this kettle.

TABLE V.

Bulb (No. II).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$$V_0 = 101.13 \text{ cc.}, \quad v_0 = 2.837, \quad 3\beta = 0.0000132.$$

After filling.	H_0	a	t	e_1	Obs.—Calcul.
1st day	415.40	0.003669			
3d "			Heated to 700°.		
4th "	415.80				
4th "			804.2°	7219	-7.4°
			906.0	8293	-4.2
			920.3	8415	-1.0
			933.7	8564	-1.0
5th "	417.05	0.003669			
7th "			909.4	8304	-1.8
			914.8	8351	-0.7
			915.4	8354	-0.4
			916.6	8367	-0.3
			917.5	8373	0.0
			918.3	8382	0.0
			918.9	8387	+0.1
			919.4	8392	+0.2
			920.0	8393	+0.7
			920.4	8398	+0.7
8th "	417.29	0.003671			

An agreement between observed and calculated values, as will be readily seen from the table, is only to be obtained near the boiling point of the zinc, or after the generation of the vapor has begun to take place freely. The high temperature 933.7° on the first day was obtained by overheating the apparatus after the zinc was for the most part evaporated.

Electric Oven.—The second bulb of this sort (No. III) was heated electrically.

The coil (see fig. 1) consisted of bare nickel wire 2^{mm} in diameter wound upon a porcelain or fire-clay tube lying horizontally. The diameter of the tube was 4.8^{cm} (inside), the length 35^{cm} and the thickness 0.3^{cm} to 0.5^{cm}. The spaces between the separate turns of wire (of approximately the same width as the wire itself) were filled with clay which baked firmly to the tube, to prevent the wire from slipping and short circuiting when hot. In order to reduce the loss of heat into

the room to a minimum, the coil was first surrounded with one, later with two concentric tubes of clay, separated from each other as well as from the coil by a thin air jacket (1^{cm}). These spaces were closed at the ends and the tubes held in place by a tight packing of asbestos. Each tube was provided at the ends with a clay cover* fitting tightly, and between the covers was also left an air space of about a centimeter. Openings were filed in the covers to admit the stem of the thermometer bulb and the insulating tubes carrying the thermo-elements. This oven, while maintaining a temperature of 1000° , consumed about 1400 watts.

The thermometer bulb lay symmetrically in the oven tube resting upon three very small pieces of fire-clay, especial care being taken that it nowhere touched the oven. For each set of measurements two or three thermo-elements were used, stretched through the oven from end to end so that the junction could be brought to any point along the bulb whose temperature was required. The fall of temperature along the bulb amounted to not more than 6° , in the mean perhaps to half that. The results obtained from the several elements were all referred to the element T_1 , a careful comparison with T_1 over the entire range of temperature having been made previously; the mean of these is the value given in the table. Inasmuch as this mean gave an excellent agreement with the gas thermometer in two so different sets of conditions (nitre bath and electric oven), and the temperature conditions within the oven can only improve as the temperature rises (compare § 6), no more accurate determination of the error due to variations of temperature along the bulb was made.

Table VI contains two sets of results obtained in this oven. In one respect the above described arrangement made a distinct gain over the previous one; with the bath the bulb had to be provided with a long bent stem for dipping into the kettle without unduly heating the sealed joint where the manometer capillary was attached; here a short straight one sufficed. The "unheated space" was thus materially diminished, and the error from this cause also. The effect of the unheated space upon t was here 9.7 per cent at 800° and 12.3 per cent at 1100° .

The temperature was not often carried over 1100° , only once a temperature of 1161.5° was reached, but directly following a large error in the ice point (1.30^{mm}) was recorded, which shows 1100° to be about the limit of the practical application of these bulbs. To be sure, differences in the zero point appear below this temperature; these in the calculation are distributed

* These clay covers (made by Haldenwanger, Charlottenburg), though perfectly able to withstand the high temperatures, were and remained of almost the consistency of chalk and could be filed or sawed at will.

among the observations of a particular series according to the time.

TABLE VI.

Bulb (No. III).—Berlin porcelain glazed inside and out. Gas—Nitrogen.

$$V_0 = 106.016^{\text{ccm}}, \quad v_1 = 2.807^{\text{ccm}}, \quad 3\beta = 0.0000132.$$

After filling.	H_0	a	t	e_1	Obs.—Calcul.
1st day	419.23	0.003672	Heated to 1000°		
2d "					
4th "	419.91	0.003669			
6th "					
				775.7°	6866 —2.7°
				826.0	7412 —3.4
				885.1	8034 —1.6
				932.1	8545 —0.9
				932.6	8553 —1.1
				934.5	8575 —1.2
				982.2	9128 —2.3
				984.6	9141 —1.7
				1058.8	9996 —2.9
				1058.3	9990 —2.8
				990.6	9203 —1.1
				897.3	8167 —1.5
				804.4	7162 —1.8
				700.6	6075 —2.4
7th day	421.12	0.003672	Heated to 1050°		
9th "					
11th "	421.61	0.003675			
13th "					
				783.1	6928 —1.1
				864.1	7797 —0.9
				924.5	8461 —0.9
				975.6	9044 —2.1
				1044.6	9824 —2.0
				1013.0	9462 —1.7
				1015.9	9496 —1.8
				945.0	8689 —1.0
				899.3	8184 —1.1
				833.0	7462 —1.1
14th "	422.33	0.003671			
16th "					
				820.2	7318 —0.5
				916.8	8352 +1.2
				1002.4	9323 0.0
				1097.9	10404 +0.5
				1127.8	10708 +0.5
				1061.8	9987 +0.9
				934.9	8559 +0.6
				861.5	7760 —0.1
18th "	422.89	0.003672			

Bulb freshly filled. H_0		a	t	e_1	Obs.-Calcul.
1st day	412.66	0.003673			
2d "			803.2	7123	+0.7
			891.8	8094	-0.3
			1003.9	9311	+2.6
			1099.6	10400	+2.6
			1161.5	11128	+1.2
			1113.6	10574	+1.4
			1029.5	9616	+1.2
3d "	413.96	0.003671			
4th "			793.8	7043	-1.2
			901.6	8200	-0.2
			999.1	9292	-0.5
			1107.4	10517	+0.2
			1049.2	9844	+0.9
			938.1	8591	+1.0
			847.8	7610	0.0
5th "	413.99	0.003675			
6th "	413.90	0.003674			
8th "	413.97				

In order to be sure that the apparatus had remained air-tight, at the close of the observations several ice points were taken on different days. These agree within the limits of the error of observation. The mean difference between observed and calculated values of $t = \pm 1.52^\circ$.

5. Experiments with bulbs glazed outside only.

The experiments with bulbs left unglazed on the inside did not differ materially from the preceding. The heating was all done in the electric oven. The old manometer was still used for the pressure measurements, but the unheated space was still further diminished by the use of a metallic cap for closing the short tube of the manometer at the top so that the correction at 500° amounted to only 4.7 per cent, at 1000° to 7.2 per cent, and at 1100° to 7.8 per cent of t .

The gas pressure was chosen considerably smaller than before, because the bulbs were to be heated above the melting point of the glazing; it was therefore necessary that the maximum pressure reached should not exceed the atmospheric pressure. The melted glazing, being thus continually pressed into the pores of the porcelain, held tight. Only a slight excess of pressure inside at this temperature suffices for the gas to filter through and escape.

Considerable difficulties were here experienced from the sticking of the melted glazing to the oven wall if the slightest contact occurred, in which case it was almost impossible to remove the bulb after cooling without cracking the glaze. It would then be no longer air-tight, nor in fact of any further

use for our purposes. In this way all the bulbs used were in a short time ruined.

TABLE VII.

Bulbs (Nos. IV and V).—Berlin porcelain glazed outside only. Gas—Nitrogen.

Bulb No. IV, $V_0 = 103.473^{\text{ccm.}}$, $v_1 = 1.770^{\text{ccm.}}$, $3\beta = 0.0000132$.

" V, $V_0 = 100.210^{\text{ccm.}}$, $v_1 = 1.664^{\text{ccm.}}$, " "

After filling.	H_0	α	t	e_1	Obs.—Calcul.
<i>Bulb No. IV.</i>					
1st day	171.02	0.003669			
4th "			545.0°	4480	0.0°
			641.5	5466	—2.1
			742.2	6505	—2.0
			843.9	7572	—0.4
			930.6	8523	—0.4
			1014.0	9485	—2.7
5th "	173.30	0.003663			
6th "			584.0	4886	—2.0
			693.8	5999	—1.8
			800.9	7126	—1.9
			896.3	8170	—2.8
			1010.2	9457	—4.0
7th "	173.26	0.003666			
<i>Bulb No. V.</i>					
1st "	122.09	0.003667			
2d "			898.3	8145	+1.5
			906.3	8260	—1.0
			901.0	8238	—4.3
Cont. to 1200°.					
3d "	125.01	0.003669			
4th "			948.8	8789	—6.1
			956.9	8884	—6.5
			957.4	8883	—5.9
			1069.7	10097	—0.8
			1080.9	10222	—0.6
			1077.1	10170	+0.2
			1080.2	10203	+0.4
			1149.0	10958	+3.4
			1150.4	10965	+4.2
			1149.2	10943	+4.9
			1157.2	11024	+5.9
			1036.3	9649	+5.2
			1029.2	9575	+4.6
5th "	126.21	0.003675			
6th "			900.8	8266	—7.0
			921.9	8505	—7.5
			987.1	9211	—5.4
Cont. to 1225°.					
			997.0	9228	+3.0
			989.4	9160	+1.4

After filling.	H ₀	α	t	e ₁	Obs.—Calcul.
8th day	126.66	0.003678			
9th "			918.3	8435	—4.8
			923.9	8502	—5.3
			943.6	8704	—3.7
			1113.6	10630	—3.5
			1117.5	10664	—2.5
			Cont. to 1215°.		
			1066.4	10008	+3.7
			1066.8	10018	+3.2
			940.9	8622	+1.0
10th "	127.10	0.0036795			
Bulb freshly filled.					
3d day	148.81				
5th "	148.85	0.003667			
8th "	148.88	0.003668			

In Table VII are given the results obtained with two of these bulbs. One (numbered IV in the table) served for measurements up to 1000° and was intended to furnish a control upon the results obtained previously from bulbs glazed on both sides.

The values given by the gas thermometer with this bulb are all too small when compared with the element T₁. It is nevertheless a matter of doubt whether this difference arises entirely from the nature of the bulb; it may be partly due to the change in the volume of the unheated space.

In regard to the changes in the zero point here noticed, it should be borne in mind that as the quantity of gas is here smaller, a small increase would produce a comparatively greater effect upon the pressure at 0°.

The other unglazed bulb (numbered V) was several times heated above 1200° and observed by rising as well as by falling temperature, as a result of which the differences between the values obtained and the normal curve are found to change sign during the heating, in fact to form a loop about the curve. The cause of this phenomenon we were not able to discover, for it was not possible, on account of the thin wall of the bulb, to heat it above 800° under vacuum, and further experiments with thick-walled bulbs could not conveniently be undertaken at that time.

A series of observations of the ice point and expansion coefficient was here also undertaken with a fresh gas filling at the close of Table VII, to see that the connections had remained tight.

In regard to the cause of the more or less systematic ice point variations throughout the observations, it is emphatically our opinion that it lies in the porcelain wall itself. The variations are always greatest after the first heating, so that quite

probably a chemical action or a setting free of absorbed gas is responsible for it. If porcelain at high temperatures were porous the change with each further heating should be as great as with the first. A change in the volume of the bulb cannot explain the phenomenon, for bulb No. III was weighed after the observations and its volume determined. The result showed an *increase* in volume amounting to 0.003, a result which would have an opposite effect to that under consideration.

Concerning the experiments of Teudt* tending to show a dissociation of atmospheric nitrogen at temperatures below 500° in which connection he has quoted experiments of Holborn and Wien, it may be said that we used the elsewhere mentioned platinum bulb at first with atmospheric nitrogen at temperatures considerably above 500° and detected no change in the gas whatever. We hope also later to investigate the behavior of porcelain bulbs with chemically pure nitrogen as well.

6. *Experiments with the platin-iridium bulb.*

The Bulb.—The platin-iridium bulb used was similar in form to the glass bulb first described and was made by the firm of Heräus in Hanau. It contained as much iridium as could be alloyed with the platinum and allow of its being properly worked—about 20 per cent. The length was 17^{cm}, outside diameter 4^{cm} and the thickness of the wall 0.5^{mm}. It was made from three pieces of sheet metal, the main cylinder and two rounded end pieces, welded together and giving of course a seam around each end and down the middle. These seams were afterward protected by a thick layer of platinum, melted and dropped on to the hot bulb—it then proved and has since remained perfectly tight. The stem where it was welded on to the bulb (welding seam also strengthened with platinum) was also made of the 20 per cent alloy for a distance of some 10^{cm} out from the bulb, where it was reduced to 5 per cent for the remaining 20^{cm} of its length. The 5 per cent alloy is much less brittle and, therefore, more convenient to handle. In outside diameter the stem was 2^{mm} and inside 0.75^{mm}. It was connected with the capillary tube leading to the manometer by means of a short overlapping glass tube sealed at both ends with sealing wax. It was possible by carefully heating to draw the sealing wax in between glass and platinum until the entire space around the ends of the two capillaries was filled, thereby adding as little as possible to the volume of the “unheated space.”

* Teudt, *Zeitschr. f. physikal. Chem.*, xxvi, 143, 1898.

The volume of the bulb at 0° was 208.222^{cm} and the weight 308 grams. The final determination of the volume was made after the bulb had been several times heated to the highest temperature observed. The volume was chosen larger than in the case of the porcelain bulbs previously used in order to still further diminish the effect of the unheated space. *The required correction here was thus only 1.1 per cent of t at 500° and 1.9 per cent at 1100° .*

Before being attached to the thermometer the bulb was boiled for several days in concentrated nitric acid. When heated to 1100° or 1200° the outside surface turned black, a phenomenon probably to be attributed to the oxidation of the iridium. Afterward, when the temperature was carried up to 1300° the bright metallic color returned—indicating a reduction of the iridium oxide.

Gas filling.—Before filling the bulb with gas it was exhausted with the mercury pump and in this condition heated, at first to 850° , *afterward to 1300°* , the pump being operated from time to time throughout and a sharp vacuum maintained even at the latter temperature.

For the purpose of having an elementary gas for the final measurements, nitrogen was generated from ammonium nitrite and passed through four wash bottles containing the usual pyrogallic acid solution, then through drying tubes and into the hot bulb, which was then allowed to cool. When it had cooled down to the temperature of the room a further small quantity of gas was added or taken away until the pressure desired for the observations was obtained. This pressure was always so chosen that at the highest temperature to be measured, the maximum pressure exerted upon the walls of the bulb would not be above one atmosphere.

Electric Oven.—The oven was similar to that used in heating the porcelain bulbs; unfortunately, however, the tubes at our disposal upon which the coils could be wound were a few millimeters smaller than might have been desired, thereby giving rise to two sorts of difficulties. First, the irregularities of temperature within the oven made themselves strongly felt on the bulb of the thermometer, and secondly, inasmuch as the space between bulb and oven wall was very narrow the wires of the thermo-elements were with difficulty prevented from short circuiting through the metallic wall of the bulb. Their insulation was accomplished in these experiments by very thin porcelain tubes slipped on to the elements wherever such a contact was possible. At temperatures of 1000° and above, however, where the porcelain begins to act sensibly as a conductor, a leakage began to be noticeable from the oven coil into

the elements through the tube carrying the coil, the three bits of fire clay which served to hold the bulb in place in the oven, and the metallic bulb itself. The error due to this leakage within the range of temperature observed (to 1150°) was readily eliminated by reversing the current in the oven.*

For temperatures above this point a larger oven is being prepared. The oven as used up to the present is shown in cross section in fig. 1.

Temperature variations along the bulb.—The difficulty caused by the variations of temperature within the oven we succeeded in overcoming for the most part by varying the winding of the coil somewhat.

Instead of a uniform space between the separate turns of wire approximately equal to the diameter of the wire (2^{mm}) as we had previously used it, it was only so wound at the ends, the turns in the middle for some 10^{cm} being twice as far apart (4^{mm}) and coming gradually closer together toward the ends, i. e. roughly, a logarithmically wound coil.

Before the oven thus equipped was used for thermometric measurements the differences of temperature at various points within were determined as follows: Two thermo-elements were melted together at their junctions and drawn from point to point through the empty tube at various temperatures. Especially thin elements were chosen for this purpose, 0.25^{mm} diameter instead of the usual 0.6^{mm} , in order to reduce the heat conducted away from the junction by the wires themselves to a minimum.

Table VIII contains the results of this trial for the old and the new oven coils, the dimensions of the tube being approximately the same for both. In the first case (uniform winding) the conditions improve with the higher temperatures, which seems to indicate that the tendency to a condition of equilibrium through radiation is stronger than the loss at the ends from conductivity. The presence of the platin-iridium bulb in the tube diminishes the irregularities some 3° at the lower temperatures, at 1000° scarcely any. The placing of fire-clay partitions in the tube close to the ends of the bulb also influences the results between 500° and 900° ; between these limits the temperature as measured by the gas thermometer is raised some 3.5° without changing the temperature relation between the middle and end of the bulb; that is, the partitions affect only the radiation from the end surfaces.

* A simple reversal of the current is insufficient for correcting a large error from this cause, as the resistance of porcelain increases with the time of passage of the current, and one must, therefore, wait until the resistance is approximately constant. In the observations here presented the reversal of the current influenced the thermo-elements about 0.5° at 1000° and 1.5° at 1100° , and some five minutes were required to produce constant conditions.

TABLE VIII.
Variations of temperature within electric oven.

Distance of thermo-electric junction from middle-point of oven.	Fall in temperature as compared with center of oven.						
	Coil wound uniformly.			Coil wound logarithmically.			
	At 640°	At 840°	At 1040°	At 620°	At 820°	At 1010°	At 1150°
4.0 ^{cm} to the right	— 3.4°	— 3.4°	— 2.7°	+ 1.3°	+ 0.6°	— 0.3°	— 0.7°
7.5 “ “	— 14.7	— 11.7	— 8.7	+ 3.5	+ 2.1	— 0.3	— 1.8
4.0 “ left	— 3.2	— 2.7	— 1.9	+ 1.3	+ 1.2	+ 1.4	+ 2.0
7.5 “ “	— 14.4	— 11.1	— 9.9	+ 1.9	+ 1.8	+ 2.7	+ 1.7
10.0 “ “				+ 0.1	+ 0.7	+ 2.4	+ 0.8

Table IX contains the results obtained with the platinum-iridium bulb in the new form of coil, excepting the first two sets, which were made with the uniform winding and partitions in the tube close to the end of the bulb. For these two cases an integral value of the distribution of temperature along the bulb as measured at the time has been added as a correction. We lay no especial stress upon the agreement of these values with the following ones and give the results only because they happen to have been made with the same gas filling. Observations during which the oven current was reversed are indicated in the table by an asterisk (*).

The values for the electromotive force e_2 refer to the element T_2 , which throughout the observations lay at the middle point of the bulb. The results obtained with the logarithmically wound spiral contain no correction for variations in temperature along the bulb, although, as may be seen from Table VIII, the ends of the bulb for the lower temperatures are somewhat overheated. The values in the last column (Table IX) give the differences between the observed temperatures obtained from the gas thermometer and those taken from a mean curve drawn through the plotted readings of the thermo-element T_2 . *The mean value of the error thus obtained amounts to ± 0.85 .*

TABLE IX.

Bulb (No. VI).—Platinum with 20 per cent iridium. Gas—Nitrogen.

$V_0 = 208.22^{\circ}\text{cm}$, $v_0 = 0.870$, $3\beta = 0.000025$.

After filling.	H_0	a	t	e_2	Obs.—Cal.
1st day	286.44	0.003662			
4th “			625.9°	5399	0.0°
			626.7	5404	+ 0.3
			710.3	6272	+ 0.6
			815.9	7408	+ 0.8
			908.4	8439	+ 1.1
			1003.5	9530	+ 1.7
			1121.6	10910	+ 4.5
			1128.3	11000	+ 3.8

After filling.	H ₀	<i>a</i>	<i>t</i>	<i>e</i> ₂	Obs.—Cal.
5th day	286·35	0·003665			
8th “			705·3	6252	—2·5
			818·9	7472	—2·0
			915·7	8565	—2·0
			1015·6	9710	—1·4
			1130·0	11074	—0·4
10th “	286·39				
19th “	286·39	0·003662			
20th “			624·3	5389	—0·6
			809·4	7346	—0·1
			903·6	8387	+0·9
			1009·7	9614*	+0·8
			1107·2	10763*	+2·3
21st “	286·36				
22d “			511·1	4239	+1·1
			512·0	4255	+0·4
			550·6	4643	—0·4
			657·8	5743	—1·4
			702·0	6206	—1·5
			754·8	6765	—1·2
			856·2	7872	—0·8
			945·0	8882	—1·1
			996·6	9488*	—1·6
			1044·8	10036*	+0·2
			1047·2	10065*	+0·2
			1096·0	10645*	+0·8
24th “	286·30	0·003663			
24th “			540·4	4539	—0·1
			541·9	4556	—0·3
			614·3	5285	—0·4
			715·4	6332	—0·1
			811·6	7375	—0·5
			915·9	8541	—0·4
			1012·5	9653*	+0·3
			1100·0	10693*	+0·8
25th “	286·31				
25th† “			515·7	4291	+0·4
			615·1	5291	—0·2
			719·2	6371	0·0
			819·1	7452	0·0
			909·7	8449	+1·6
			1020·8	9748*	+0·5
			1127·5	11025*	+1·1
26th “	286·79	0·003662 _s			
Bulb freshly filled.					
1st day	294·34	0·003666			
2d† “			528·3	4416	+0·2
			613·6	5277	—0·3
			1003·8	9547*	+0·6
4th “	294·33				

† At the close of the observations the oven was maintained for a considerable time at 1300°.

Table X gives the values of the E. M. F. for the element T_2 .

TABLE X.
Thermo-element T_2 .

	Microvolts.		Microvolts.
500°	4141	850°	7794
550	4633	900	8356
600	5135	950	8927
650	5647	1000	9507
700	6169	1050	10101
750	6700	1100	10703
800	7242	1150	11315

Expansion coefficient of platin-iridium.—In regard to the calculation of the temperatures given by the gas thermometer with the platin-iridium bulb, attention should be called to the fact that the round number 0.000025 has been adopted as the coefficient of volume-expansion of platin-iridium (3β).

This corresponds for a 20 per cent alloy to the figures given by Benoît* for observations upon pure platinum, pure iridium, and a 10 per cent alloy for temperatures 0°–100°.

It is probable that this coefficient is higher at higher temperatures, but few trustworthy observations are at hand. We have found only the papers of Le Chatelier† and Seliwanow.‡ The former gives as a preliminary result for a 10 per cent alloy between 0° and 1000° an expansion coefficient some 30 per cent higher than 0°–100°; the latter for platinum 0°–1650° gives a result only 11 per cent higher than at the lower temperatures. The temperature measurements is however, in the latter case, uncertain.

Table IX shows the values for the ice point (H_0) and coefficient of expansion (α) to be nearly constant. After the last heating, made with the first gas filling, a considerable increase in H_0 will be noticed which, however, is solely due to the fact that the temperature was carried for the first time up to 1300°. Afterward when the bulb had been evacuated and freshly filled at 1300° a second heating to the same point showed no change in the ice point whatever.

In order to accomplish this result great care is necessary in the choice of the material used in the construction of the oven. We include herewith ice points from an earlier series of observations where a sudden and sharp increase occurred which could be foreseen during the progress of the heating. The outer mantle of the then new oven consisted of sun-dried

* Benoît, Trav. et Mém. du Bur. internat., vi, 190, 1888.

† Le Chatelier, C. R., cviii, 1096, 1889.

‡ Seliwanow, Journ. d. russ. phys. Ges., xxiii, II, 152, 1891.

(unburned) clay containing organic substances which burned when the bulb reached a temperature of 1000° , as could be readily detected by the odor in the room. The air thermometer at once began to go up and continued doing so for some minutes, though the thermo-element in the oven showed the temperature inside to be actually falling. This plainly showed that the gases of combustion were penetrating into the bulb in spite of an excess of pressure within of a full atmosphere. Further observations were suspended for the time and the oven allowed to cool, when the ice point was found to have risen 4.46^{mm} .

The zero points for the series follow:

Bulb freshly filled.....	296.67 ^{mm} Hg.
After heating to 1085°	296.66 “
After standing undisturbed for 18 days	296.66 “
After heating as above described.....	301.12 “

7. Conclusion.

We have then as a result of the foregoing investigation two curves based upon the thermo-elements T_1 and T_2 respectively. If we compare these we shall obtain the difference between the temperature scale measured with porcelain bulbs and that secured from the platin-iridium bulb. In Table XI this difference Δ is given in microvolts and in degrees.

TABLE XI.

	$T_2 - T_1$ Microvolts.	Δ	
		Microvolts.	Degrees.
500°	93	4	0.4°
550	101	1	0.1
600	107	1	0.1
650	115	1	0.1
700	122	3	0.3
750	130	4	0.4
800	138	8	0.7
850	147	13	1.2
900	156	20	1.8
950	165	28	2.4
1000	174	39	3.3
1050	183	55	4.6
1100	192	77	6.4
1150	201	105	8.5

The difference, as will be seen, always has the same sign, that is, the scale founded upon the porcelain values always gives a somewhat higher value for the temperature than the other. In the lower part of the scale the Δ chances to be smaller than

the errors of observation ; even in the vicinity of 1000° it is not higher than the possible error in the value assumed for the coefficient of expansion of the bulb (3β). An increase of 10 per cent in 3β causes an increase of 1.5° at 1000° for the porcelain scale and 3.2° for the platinum. Above 1000° the values of Δ increase rapidly. The values obtained from the platinum bulb must be accorded the preference, however, not only on account of the constancy of ice point and coefficient of expansion but on account of the much reduced error due to the unheated space.

It is not impossible that at high temperatures a vapor is developed in the porcelain bulbs, in fact in the bulbs containing glazing this could quite naturally take place.

Our purpose is to continue the observations with the platinum bulb to still higher temperatures and to investigate a second similar bulb which the firm of Heräus has kindly placed at our disposal. The coefficient of expansion (3β) and the effect of pressure at the higher temperatures will also be determined.

Dr. Hans Usener, who undertook this investigation with us and carried on for a considerable time the thermo-electrical observations, left it to accept a position at the German Government Torpedo Station at Kiel.

Charlottenburg, June, 1899.

ART. XIX.—*On the Flicker Photometer*; by OGDEN N. ROOD, Professor of Physics in Columbia University.

IN the September number of this Journal, 1893, I published an account of "A photometric method which is independent of color," the principle being, that when two colored surfaces are presented in rapid succession to the eye, the resulting flicker vanishes when they have the same luminosity. My experiments were afterward repeated and amplified by Dr. F. L. Tufts, who obtained confirmatory results.* In my paper I also remarked, that "there does not seem to be any reason why this process, with the aid of well known optical devices, should not be applied to ordinary photometric work, or to such as is carried on in the interior of the observing telescope of a spectro-scope."

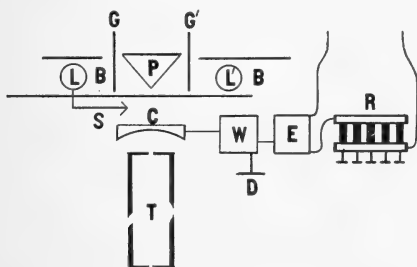
In 1896 Prof. F. P. Whitman devised a photometer with a revolving card-board disc, in which the proposed flicker method was utilized, and which gave satisfactory results.† On Nov. 17th, 1896, I read a paper before the National Academy of Sciences, in which were described four methods in which the flicker process could be employed photometrically: (a) by the use of convex or concave lenses oscillating at proper rates, (b) by a vibrating plane mirror, (c) by a revolving glass prism of small angle, (d) by a revolving plane mirror set excentrically on its axis. Apparatus embodying these ideas had at that time been constructed and used by me. In 1897 I constructed a complete photometer, using an oscillating convex cylindrical lens, and made many measurements with it. The instrument was briefly described in *Science*, June 3d, 1898, and a week later, in the same periodical, appeared a short account of some quantitative observations made with it on color-blindness. Since that time, the convex cylindrical lens has been replaced advantageously by one that is *concave*, and the paper prism previously used by one of plaster of Paris. The field has also been very much contracted, and other improvements introduced, particularly in the matter of uniformity of rate of oscillation and choice of such rate.

The general idea of the photometer is that the differently colored beams of light traversing its axis should illuminate the two surfaces of a rectangular prism, P, facing the eye, and that by the oscillations of a cylindrical concave lens, C, in front of the prism, its illuminated surfaces should alternately and in

* Transactions of the New York Academy of Sciences, xvi, 190–212, April, 1897.

† Physical Review, vol. iii, No. 16, Jan.–Feb., 1896.

rapid succession be presented to the eye. One incandescent lamp, L' , remains stationary; the other is moved by the observer till all flicker disappears, when a reading is registered on a fillet of paper, which is not inspected by the observer till the conclusion of the operation. In many of my experiments the light was colored by transmission through plates of colored glass, G , G' , and was almost spectral in hue. On a strip of board, B , 8 c. broad and 3.3 m. in length, graduated in centimeters, the incandescent lamps are placed, suitable guides keeping them in the axis of the instrument. One of the lamps can be moved by a long slender strip of wood, S , to which is attached a fillet of paper to receive the observations, which are impressed on it by a pin-point suitably arranged. The other lamp is stationed where in each case it is found desirable.



The prism, P , is fastened on the center of the long board at the common zero point of the two sets of graduations, and the most important thing about it is, that its two faces should meet in an invisible line; otherwise the juncture, not being illuminated, appears in the field as a vertical black line, and this will of itself furnish a faint flicker, that becomes apparent after the flicker from the faces of the prism has disappeared. Good prisms, free from this defect, can be made by casting plaster of Paris in a mould composed of glass plates, suitably ground on their edges. These plates can be removed from the plaster by the gentle heat of a spirit lamp, without damage to the dividing line between the faces of the still moist prism. When heat is applied, the plates fall off of themselves. With paper prisms, however well prepared, it is impossible entirely to get rid of the black dividing line, and the observer is obliged to rely on obtaining a minimum flicker.

With the above object still in view, it is best to use a *concave* cylindrical oscillating lens, which diminishes still further the bad effects of any want of perfection in the prism; that employed by me had a focus of 13 centimeters; its outline was square, the sides being 4 centimeters in length. It was placed

parallel to the line where the prism faces meet and also parallel to the axis of the instrument. Its distance from the prism was 16 centimeters.

The observing tube, T, had a length of 21 and a diameter of 4 centimeters. It was placed at right angles, both to the vertical axis of the prism and to the axis of the photometer. Both ends of it were furnished with diaphragms pierced by apertures 5^{mm} in diameter; the end next to the cylindrical lens should be brought as near to the lens as practicable. The visible field thus obtained is rather small, but quite sufficient, larger fields having been found to give inferior results, particularly in the hands of untrained observers.

In the apparatus as at present arranged a small electromotor, E, is used to give the cylindrical lens the proper oscillatory movement through the intervention of a train of toothed wheels, W. The speed of the motor is regulated in the following way: a current is employed more than sufficient to drive the motor at proper speed, and the strength of this current is reduced by the introduction of a variable resistance, R, composed of five glass tubes, each of which is 13 centimeters in length with an internal diameter of 2 centimeters. The tubes are filled with a mixture of coarse graphite and asbestos, which can be more or less compressed by the aid of five screws provided with plungers. As each tube carries only the fifth of the current, the rise in temperature is inconsiderable. The idea of employing the mixture for a variable resistance was borrowed from Dr. Hallock. In this way the speed of the oscillating lens can be regulated and kept constant for a long time. For the sake of convenience, a rotating card-board disc, D, is attached to W, and provided with a proper number of black and white sectors. Its appearance enables the observer to judge whether the proper rate of speed is being employed.

The photometer is most sensitive, that is the flicker is strongest, when the rate of oscillation is such that the two colored surfaces in the field are just fairly blended by the movement of the lens, and cannot be distinguished separately. The rate of lens oscillation usually employed has been about sixteen per second, more or less. When the illumination is feeble, low rates are preferable; when it is strong, higher rates are better, and some persons seem to have a general preference for rather high rates, which while diminishing the sensitiveness somewhat, also abolish flicker due to imperfection in the prism.

Finally, movable screens of black pasteboard are arranged around the prism, observing tube, and partially around the head of the observer, in such a way that all extraneous light is cut off.

The mode of making the observations is much the same as with ordinary photometers; by a preliminary experiment the position of flicker disappearance is approximately ascertained, and then the moving lamp is displaced till a distinct flicker is noticed; it is then brought up till this disappears, and the operation repeated in the reversed sense, both observations being recorded. From time to time wider excursions are made, to avoid the danger of "falling into a rut." Two fiducial marks are finally impressed on the fillet of paper, which is removed and read with a lens and millimeter scale. Persons trained in laboratory work usually obtain good results in their first trials; this was the case with Miss Furness, Dr. Dennett, Professor Hallock and some of the laboratory assistants. In other cases a certain amount of training was found necessary, which seemed to be due to the fact that the attention of the observer was allowed to wander from flicker-perception to color-perception, and to the changes in it due to the position of the movable lamp. With the small field now employed, there is no eye-fatigue, except that incident on looking steadily into any kind of tube for some minutes.

In order to furnish an idea of the degree of accuracy attainable, I give below sets of results obtained by myself when using three pairs of colors, red and blue, red and green, green and blue. The colored light was furnished by colored glass, and was to all appearance spectral in its purity. One face of the prism being illuminated with red light from the stationary lamp, the other received violet-blue light from the movable lamp, which was adjusted till the flicker vanished, and its mean distance from the edge of the prism obtained, ten observations being made. For certain purposes this operation was repeated on seven different days. Taking the mean distance of all seven results as correct, and as corresponding when squared to 100 per cent, I calculated the deviations from this in each of the seven cases in percentages.

Red and Blue.		Red and Green.		Blue and Green.	
	Diff.		Diff.		Diff.
Dec. 13	-0.26	Feb. 2	-0.89	Jan. 5	+3.5
" 16	+1.74	" 3	+2.60	" 16	+0.01
Jan. 5	+0.4	" 11	+1.10	" 17	-1.91
" 13	-0.26	" 15	-1.69	" 18	+0.84
" 16	-1.57	" 17	-0.35	" 24	-1.26
" 17	-0.26	" 20	-1.95	" 25	-1.26
" 18	+0.3	March 1	+1.29		

Similar results are also given above for the pair red-green and green-blue. No account is taken of possible variations in the

relative intensity of the two lamps, since such variation would at least not have tended to increase the accuracy of the results.

In order to exhibit the working of the instrument in the hands of other persons, I give below results obtained by six good observers, with each of whom I compared my own color-vision; they contain an element which furnishes a rather severe test of the correctness of the whole procedure that is entirely wanting in the tables above given. Each of the six persons was successively, for the time being, assumed to have standard color vision, viz: their perception of red, green and blue was taken as 100 in each case, and I determined my variations from it, both of us using the pairs, red-blue, red-green, and blue-green. In this mode of procedure it was possible to obtain two values for my perception of green as compared with theirs, a direct one founded on our joint experiment on the pair red-green, and an indirect one derived from our joint observations on the pair green-blue, my value for blue having first been obtained by a third joint experiment on the pair red-blue. If all the readings obtained by the person used as a standard and by the one undergoing examination are correct, then the direct and the indirect value for the green should coincide. Attention is again called to the fact that the indirect value is obtained by the use of an *intermediate* color. Below is a table showing the variations in percentages between these direct and indirect values of the green.

Dr. Dennett	—0.32	Mr. Parker	+1.77
Miss Furness	—1.04	Dr. Tufts	+3.17
Dr. Hallock	+0.41	Mr. Wade	—0.69

The general conclusion to be drawn from the numerical results given in this paper would seem to be, that the accuracy attainable with the flicker photometer, as at present constructed and using light of different colors almost spectral in hue, is about the same as with ordinary photometers using plain white light, or light of exactly the same color.

New York, May 8th, 1899.

ART. XX.—*A Quantitative Investigation of the Coherer;*
by A. TROWBRIDGE.

SINCE the very remarkable success of G. Marconi in the field of wireless telegraphy, a renewed interest has been felt by physicists in the coherer, the apparatus devised by Branley which has made wireless telegraphy possible.

Besides the original paper* of Branley there have been a number of communications on the subject of coherer action; in particular those of Dorn† and Aschkinass,‡ which have thrown much light on the subject. As yet, however, the experimental data are not complete enough for a perfectly satisfactory theory of coherer action to be formed, those already existing being seemingly inadequate to explain all the observed phenomena.

Even if we do not know just what takes place in the coherer itself, we know that the cause of the fall in resistance is primarily an electro-magnetic disturbance in the space surrounding the coherer. This disturbance will induce a static wave in a conductor whose direction in space coincides with the direction of the lines of electric force from the source of the electro-magnetic disturbance. If this static wave is the cause of the lowering of the resistance of the coherer, then a static discharge from a Leyden jar, or electrophorus, through the coherer, should produce a like effect. This conclusion was verified by Professor Henry S. Carhart and myself while we were engaged a few months ago in testing the sensibility of coherers for telegraphic purposes. If this conclusion is warranted, then on the nature of the discharge and the quantity of electricity which goes through the coherer should depend the fall of resistance of the latter.

The present paper has to deal with the lowering of the resistance as a function of the quantity of electricity discharged through and the difference of potential on opposite sides of the coherer.

In order to test the supposed relation between quantity of electricity discharged and the fall of resistance in the coherer, I adopted the following arrangement.

By means of a charge and discharge key, a subdivided condenser could be charged from a large storage battery, the electromotive force of which could be varied at will from 2 to 70 volts, and then discharged through the coherer. The capacity at my disposal could be varied from 3·2 microfarad to 0·05

* Compt. Rendus, cxi.

† Wied. Ann., lxvi, p. 146.

‡ Wied. Ann., lxvi, p. 284.

microfarad, and this range, taken together with that of the storage battery, made it possible to vary the product $CV = Q$, within a comparatively large range, the upper limit of which, however, was only 224 micro-coulombs.

For the purpose of measuring the fall of resistance, a branch circuit containing a single storage cell (E. M. F.=2 volts) and a milli-ammeter was connected to the ends of the coherer. The limit of accuracy in reading the milli-ammeter was 0.001 ampere.

With a coherer of the type described by Marconi, I found, as I expected, an increase in conductivity with an increase in quantity of electricity sent through the coherer; however on increasing Q beyond a certain point, the corresponding increase in conductivity was very small; for the coherer in question, for example, the increase in conductivity was very rapid on increasing Q up to about 15 micro-coulombs, but beyond this point, doubling the quantity only produced a fractional change in the conductivity. It seemed as if the 15 micro-coulombs were enough to produce all, or nearly all, the lowering possible for the coherer in question and for the given charging potential (a point I will explain presently).

As the results obtained with the above mentioned coherer were not concordant enough for quantitative work, I adopted another type which I have since seen described in a paper by Branley,* in which he claims that it is more sensitive than the older form.

The coherer I used consisted of 21 bicycle pedal balls (diameter 3^{mm}) mounted in a horizontal glass tube of about the same bore, the end balls being soldered to lead-wires and the tube being provided with a device for adjusting the pressure of contact between the balls. The normal resistance of this coherer was about 2000 ohms, care being taken always to return to about this resistance by tapping the tube and adjusting the pressure before an observation was taken on the fall of resistance due to the discharge of the condenser. M. Branley used hard steel balls 12^{mm} in diameter—those first used by me were 9.5^{mm} in diameter, but I found the smaller ones finally used to be much better suited to my purpose, at least, and I should judge that this would also hold true for telegraphic purposes.

However, I made no attempt at long-distance telegraphy with my coherer, having only satisfied myself that, at short range, the ball coherer behaved in all respects like a filing coherer.

The method of observation was the following: With a given charging potential the capacity was varied through the limits

* Comptes Rendus, No. 18, May, 1899.

above mentioned: for each capacity the mean of about 20 observations was taken on the lower limit of resistance attained by the coherer on discharging the capacity through it; this resistance being indirectly obtained by Ohm's law from the readings of the milli-ammeter.

As I have mentioned above, the upper limit, or normal resistance of the coherer was arranged to have a uniform value of about 2000 ohms.

Next, the charging potential was given another value and a like set of observations taken, and so on through the range of the charging potential.

It was at once evident that the lower limits of the resistance was not the simple function of the quantity of electricity sent through the coherer that I had expected. If this had been the case, I should have found the lower limit of the resistance the same for the cases $Q = C_1 V_1 = C_2 V_2 = C_3 V_3$, etc. = constant. From my observations this was distinctly *not* the case.

I found that for $Q = \text{constant}$, the larger the charging potential—and hence the smaller the capacity—the lower was the final resistance or the greater the conductivity of the coherer after the discharge.

I have given the results of my observations on the ball coherer in curves 1 and 2. A table of the numerical values I obtained I have not given, since it would be of little theoretical import, as it would hold only for the coherer I used. The form of the curves given should, I believe, be similar for all coherers.

In curve 1, the abscissas represent the reciprocals of the lower limit of resistance of the coherer, or the conductivity; the ordinates, the quantity of electricity sent through. The seven different curves represent the change in conductivity as a function of the quantity for the seven different charging potentials used; the indices $V=10, 12, 18$, etc., denoting these potentials.

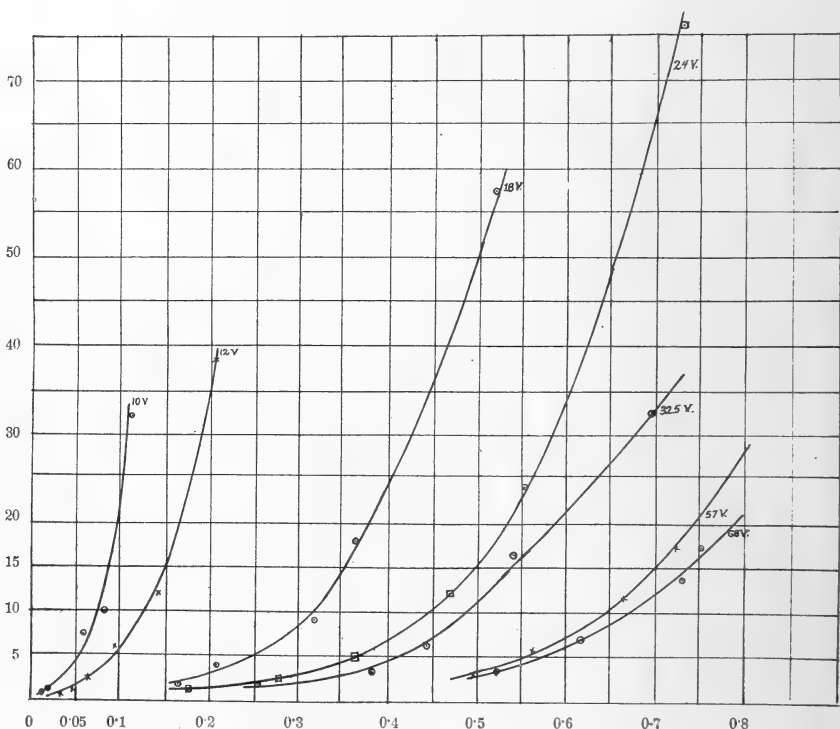
As will be seen, all the curves tend in a general way, as they should, towards a point on the conductivity axis, very near the origin; a point which would denote the reciprocal of 2000 ohms, the normal resistance. Also it is clear that the greater the charging potential, the more rapid the rise of the conductivity per unit increase in quantity discharged.

I was unable, with the coherer used, to get coherer action when the charging potential of 8 volts and under was used. This point is brought out by the set of curves No. 2, in which the abscissas are the same as in curves No. 1, while the ordinates represent charging potentials. All the curves $Q = \text{constant}$ cut the ordinate axis at a point $V = 8.75$ volts. This is, so to speak, the critical voltage for the coherer under

examination. Unless a potential difference between the terminals of the coherer of at least this value is produced by the electromagnetic disturbance, no coherer action will take place.

Probably every coherer has a critical value of the potential difference peculiar to itself, a coherer with a low value being preferable for telegraphic purposes. Owing to lack of time I have not been able to experiment with more than one coherer.

1



When we inquire into the nature of the discharge through the coherer which produces a lowering of resistance, the question arises as to whether or not it is of an oscillatory character.

From the theory of the oscillatory discharge of a condenser, we have a term

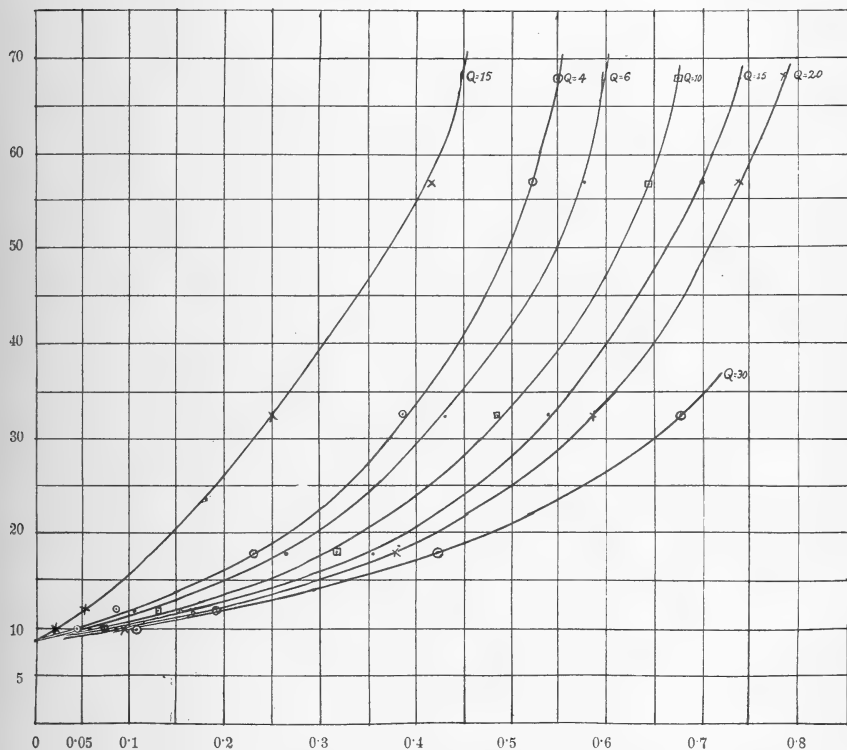
$$\sqrt{r^2 - 4 \frac{L}{C}}$$

entering into the expression for the current strength I , where r is the resistance of the discharge circuit and L and C respec-

tively the self-induction and capacity. If $r^2 < 4 \frac{L}{C}$, an imaginary quantity enters into the expression for I, this is the condition for a periodic discharge. If, on the other hand, $r^2 > 4 \frac{L}{C}$, we have an aperiodic discharge.

Under the conditions present in my investigation, the latter case was certainly realized, for r normal was 2000 ohms, C

2



from $3.2 \cdot 0.05$ microfarad and L certainly very small, say less than 0.01 quadrant.

$$r^2 = 4 \cdot 10^6 \text{ ohm} = 4 \cdot 10^{24} \text{ cm. sec.}^{-1}$$

$$C = 0.05 \text{ microfarad} = 5 \cdot 10^{-17} \text{ cm.}^{-1} \text{ sec.}^2$$

$$L = \text{say } 0.01 \text{ quadrant} = 10 \cdot 10^6$$

$$4 \frac{L}{C} = 4 \frac{10 \cdot 10^6}{5 \cdot 10^{-17}} = 8 \cdot 10^{23} < [4 \cdot 10^{24} = r^2]$$

As L is certainly less than the value here assumed, the discharge circuit being a short straight copper wire, it is evident

that $r^2 > 4 \frac{L}{C}$, or that the discharge which affects the lowering of resistance in this investigation was aperiodic. I tested this point experimentally in the following manner: the condenser was removed and the lead-wires from the storage battery to the ends of the coherer were provided with a key and a thin $\frac{1}{10}$ ampere fuse-wire in series. When the key was closed a steady current flowed through the coherer—the voltage of the storage battery was varied through a range of from 8–70 volts, and the lowering of the resistance of the coherer was again found to vary as the voltage. Owing to the element of time entering into the problem (the time elapsing from the closing of the key to the blowing out of the fuse), it was not possible to make quantitative observations on the fall of resistance. It was evident, however, that a steady current did produce this drop in resistance, that the drop was greater the greater the electromotive force of the storage battery, and further, as I had before noted, that for an electromotive force less than from 8–10 volts no coherer action took place.

Now we can regard the coherer with its vertical wire and earth connection, as it is used by Marconi, as part of the discharged circuit of a condenser whose plates are the vertical wire and the earth. A certain potential difference between vertical wire and earth is caused by the electromagnetic waves sent out from the Herz oscillator; this potential and the capacity of the vertical wire—earth condenser determine the quantity of electricity which is discharged through the coherer in the form of an aperiodic impulse and which produces the lowering in resistance necessary to wireless telegraphy. The potential difference on opposite sides of the coherer must be an inverse function of the distance between sending and receiving stations; if this distance is small, the potential difference being above what I have called the critical potential for the coherer used, if we increase the capacity of the vertical wire we shall increase the fall in resistance of the coherer, but if the distance is so great that the potential is at about its critical value, then an increase in capacity would lower the potential and so diminish or destroy the sensibility of the coherer.

This would explain Marconi's statement that at short distances a capacity consisting of a cubical tin box mounted at the top of the vertical wire, increased the sensibility of the coherer, but that he found it advisable to omit this capacity when telegraphing long distances.

It is also evident that one precaution must be taken when using a very sensitive coherer for wireless telegraphy. Since

a steady current will produce coherer action if the potential difference between the ends of the coherer exceed what I have called the critical voltage, and since the lower this critical value is, the more sensitive will be the coherer for long-distance work, care must be taken that the electromotive force of the battery which operates the relay in Marconi's arrangement, shall have a value less than the critical value for the coherer used.

If an electromotive force of about the critical value is used, we might expect to notice a confusion of the signals from the sending station due to the local circuit through the coherer producing an independent and quite irregular lowering of the resistance.

Everyone who has attempted wireless telegraphy has probably been annoyed by extra "clicks" of the instrument. I believe it is in many cases attributable to the cause just mentioned; in which case it could be done away with by so choosing critical potential of coherer, electromotive force of battery in coherer circuit, and sensibility of the relay, that the first should be higher than the second, while the third should be great enough to permit of a small absolute value of the other two.

In conclusion, I should like to take this opportunity to express my thanks to my colleague, Dr. Karl Guthe, for his kindly interest in the present investigation, and for numerous helpful suggestions.

Physical Laboratory of the University of Michigan, June, 1899.

ART. XXI.—*The Double Ammonium Phosphates of Beryllium, Zinc, and Cadmium in Analysis*; by MARTHA AUSTIN.

[Contribution from the Kent Chemical Laboratory of Yale University—LXXXVI.]

IT has been shown* that the composition of the phosphate of manganese thrown down by microcosmic salt from the solution of a pure manganous salt contains more manganese than belongs to the ideal ammonium manganese phosphate NH_4MnPO_4 ; and, further, that by acting with ammonium chloride in proper proportion the phosphate of manganese thrown down by microcosmic salt may be completely converted to the ideal ammonium manganese phosphate. Ammonium chloride, likewise, in the case of magnesium phosphate† tends to cause the replacement of the metal by ammonia. Indeed, the replacement here is readily carried so far beyond the point corresponding to the normal ammonium magnesium phosphate, NH_4MgPO_4 , that the tendency to form a salt richer in ammonia and poorer in magnesium—perhaps something like $\text{Mg}(\text{NH}_4)_4(\text{PO}_4)_2$ —must be recognized.

These facts suggested an investigation into the constitution of certain other ammonium phosphates with reference to their utility in analytical processes. Of the elements of Mendeléeff's second group, beryllium, magnesium, zinc, cadmium and mercury are capable of yielding double ammonium phosphates, while no such compounds of calcium, strontium and barium have been described. The solubility in ammonia of the double ammonium phosphates of the elements of the former category appears to increase as the elements of which they are compounds are removed in the series from the beryllium, and, while the same is true of the simple phosphates of members of the latter category, the extent of such solvent action is slight comparatively. According to the work recorded in the literature, calcium, barium, and strontium form individually a neutral tribasic phosphate or acid phosphates of greater or less degree of acidity according to the conditions of precipitation. In my experience where salts of these elements were precipitated either with ammonium phosphate or microcosmic salt in presence of varying amounts of ammonium chloride, or ammonia, or both, only the recognized phosphates were obtained. The effect of ammonium salts in presence of ammonia seemed to promote the formation of the tribasic salt in the case of calcium and strontium; barium tends to form the barium acid phosphate almost exclusively even in the presence of ammonium

* This Journal, vol. vi, 233.

† This Journal, vol. vii, 187.

salts and free ammonia. No double ammonium phosphate of either calcium, strontium, or barium was produced under any condition. As is well known, mercury does form an ammonium mercury phosphate, but the salt is soluble to so great a degree in ammonia, ammonium chloride, and even in the precipitant itself, that nothing of any value for analytical work seemed likely to come from its study.

The Ammonium Beryllium Phosphate.

The ammonium beryllium phosphate has been described by Roessler* as a crystalline salt produced by boiling some time in ammoniacal solution the phosphate precipitated by ammonium phosphate, though the best results of this treatment failed to yield the ideal constitution of this salt, NH_4BePO_4 . This same precipitate can not be obtained, Roessler further states, by using a sodium salt as the precipitant. In order to follow out this work of Roessler, a solution of beryllium chloride for use was prepared as follows: The pure beryllium chloride of commerce was dissolved in as little water as possible and treated for the precipitation of aluminum by etherial hydrochloric acid.† After filtering and evaporating from the filtrate the ether and a part of the hydrochloric acid, the beryllium was precipitated with ammonia, filtered to remove any members of the magnesium group, and washed free from ammonium chloride. The larger part of the precipitate was dissolved in hydrochloric acid in slight excess, and boiled with the reserved portion. After filtering, the solution was diluted to definite volume and standardized by precipitating measured portions of the solution with ammonia, filtering on asbestos under pressure in a perforated platinum crucible, igniting the residue and weighing as the oxide. The results recorded in section A of the following table were obtained by precipitating definite volumes of the pure solution of beryllium chloride with ammonium phosphate in a platinum dish, dissolving the precipitate in hydrochloric acid in faint excess, and while hot precipitating slowly with dilute ammonia, boiling (while the solution was kept distinctly ammoniacal) until the flocky precipitate was entirely converted to a fine, powdery, semi-crystalline, rapidly subsiding mass. A quarter to a half hour is necessary under the most favorable conditions to cause this conversion. After cooling, the precipitate was filtered off on asbestos under pressure in a perforated platinum crucible, washed carefully with distilled water, dried, ignited and weighed. The filtrate was tested for beryllium by boiling

* Fresenius, *Zeitschrift für analyt. Chemie*, 1878, 148.

† This Journal, vol. iv, 111.

with ammonia. None was found in these cases, nor in any of the following work. Faint traces of chloride were found in the residues after ignition after dissolving in nitric acid and testing with silver nitrate.

The results are in every case in excess of the theory for the pyrophosphate derived by ignition of the ammonium beryllium phosphate, possibly because the ammonium chloride present may have a tendency to form a salt too rich in ammonium (as was shown to be the case with the magnesium salt), consequently giving too much phosphoric acid in the ignited residue; or, because of inclusion of the chloride and phosphoric acid. It might reasonably be expected that some phosphoric acid may be held since a trace of chloride was found. Either or both of these substances may have been held mechanically, or in combination.

It was found that by boiling for some time the solution of beryllium chloride with microcosmic salt—(6) section B of the table—precipitating in the same manner as when ammonium phosphate was used—that the same sort of powdery mass remained as was obtained by the ammonium phosphate. The residue being tested for sodium according to the method brought out by Kreider and Breckenridge,* showed sodium present to the amount of 0.0062 grams reckoned as sodium phosphate. It may be reasonably supposed that the presence of the sodium was due to one of two causes, inclusion of the soluble phosphate, or to a tendency on the part of the beryllium to form an ammonium† sodium beryllium phosphate or a sodium‡ beryllium phosphate, both of which are known to exist. Long boiling of the precipitates is tedious, and, unless great care is taken, may involve small losses of material; hence if the same results could be obtained with less boiling such treatment would be decidedly advantageous. The results in section C of the table were obtained by adding microcosmic salt to the hot solutions of the chloride, boiling five minutes, cooling, filtering off on an ashless filter—because of the flocky condition of the precipitate—treating as usual before igniting the residue in a platinum crucible. The results compare well with those obtained by long boiling of the precipitated beryllium—although all are in excess of the theory. That ammonium chloride here, as in cases above, has a marked effect in changing the constitution of the phosphate precipitated by microcosmic salt is not readily seen. It is obvious that the presence of an excess of the soluble phosphate is essential to

* This Journal, vol. ii, 263.

† Persoz, Liebig's Annalen, lxxv, 174; Atterberg, Bulletin d. l. Soc. chim. d. Paris, xxiv, 358.

‡ Scheffer, Liebig's Annalen, cix, 144.

precipitate the beryllium as the double ammonium phosphate from the results recorded in section D of the table, where, after the precipitate of beryllium phosphate had subsided and the supernatant liquid had been poured off, the precipitate dissolved in hydrochloric acid was brought down again at the boiling temperature with ammonia either alone or in presence of ammonium chloride. The results obtained show that the salt approaches the constitution of the tribasic phosphate, when it is precipitated in presence of a faint excess of phosphoric acid, even though ammonium chloride in large amount be present.

TABLE I.

Be ₂ P ₂ O ₇ corresponding to BeCl ₂ .			Be ₃ P ₂ O ₈ corresponding to BeCl ₂ .			(NH ₄) ₃ PO ₄ . gram.	NH ₄ Cl gram.
Taken. gram.	Found. gram.	Error. gram.	Taken. gram.	Found. gram.	Error. gram.		
A.							
(1)	0.3578	0.3613	0.0035 +			2	--
(2)	0.3578	0.3808	0.0230 +			2	--
(3)	0.3578	0.3707	0.0129 +			2	--
(4)	0.3578	0.3640	0.0062 +			2	--
(5)	0.3578	0.3680	0.0102 +			2	30
B.							
HNaNH ₄ PO ₄ .4H ₂ O							
(6)	0.3578	0.3697	0.0119 +				
C.							
(7)	0.3578	0.3618	0.0040 +			1.2	--
(8)	0.3578	0.3680	0.0102 +			1.2	--
(9)	0.3578	0.3729	0.0151 +			1.2	10
(10)	0.3578	0.3631	0.0053 +			1.2	60
D.							
(11)			0.2700	0.2589	0.0111—	0.5	----
(12)			0.2700	0.2989	0.0289 +	0.5	—10
(13)			0.2700	0.2936	0.0236 +	0.5	5-60
(14)			0.2700	0.2507	0.0193—	0.5	—60

From the work described it is clear that the ammonium beryllium phosphate is not obtained in ideal condition by precipitating a solution of the chloride with ammonium phosphate. Roessler's own results were likewise only approximately correct, as he states. It is also plain that hydrogen sodium ammonium phosphate precipitates the ammonium beryllium phosphate in a condition as nearly ideal as does the ammonium phosphate, while the effect of the ammonium chloride in either case is not marked in producing a phosphate containing ammonia. Of most importance in obtaining the ammonium salt is an excess of the soluble phosphate, for when the amount of the precipitant is reduced to a little more than the theoretical amount the condition of the phosphate coincides almost exactly with the theory for the tribasic phosphate, even though a large

excess of ammonium chloride be present. When there is an abundance of the precipitant the results are all in excess of the theory, which may be accounted for on the supposition that foreign material is included—the chloride of ammonia and the soluble phosphate—to a greater or less extent by the precipitate. The formation of a phosphate of beryllium containing too much ammonia and phosphoric acid, or, in case of the precipitations by microcosmic salt or sodium by the formation of a sodium ammonium beryllium phosphate and sodium beryllium phosphate (known salts) is not definitely proved.

The Ammonium Zinc Phosphate.

Debray,* Bette† and Heintz‡ separately found that ammonium zinc phosphate is formed by boiling a solution of zinc sulphate with ammonium phosphate. This salt was investigated later by A. Guyard (Hugo Tamm),§ who found that if to a solution of a zinc salt of an organic or a mineral acid supersaturated with ammonia until all the zinc oxide is dissolved and made faintly acid with hydrochloric acid, sodium phosphate be added, a flocky precipitate resulted, which on being kept near the boiling point for some seconds was converted to crystalline zinc ammonium phosphate, which filtered readily and was washed free from impurities with the greatest facility. He found that all the zinc in solution was thrown down as the ammonium zinc phosphate, which on ignition yielded the zinc pyrophosphate. With care in handling this process to avoid an excess of the precipitant, and the presence of sodium and potassium salts (on account of the danger of occlusion) the precipitation of the ammonium zinc phosphate, ignition, and weighing as the pyrophosphate made, Guyard believed, an ideal process for the estimation of zinc. Although there was slight solubility of the salt, it made an insignificant loss when the process was handled properly. Acids present, or certain alkalis to any great extent, increased the solubility of the salt so much that the loss became appreciable. Another source of error was to Guyard's mind loss of zinc during the ignition of the zinc ammonium phosphate with the paper on which the precipitate had been collected. Garrigues|| found, in estimating zinc in a practical way, that this process advocated by Guyard gives in solutions of zinc free from salts of all metals, even alkaline salts—solutions that from previous steps in analysis, however, must have contained ammonium chloride in large amount—as satisfactory results as Guyard claimed for it.

* Comptes Rendus, lix, 40.

† Liebig's Annalen, xv, 129.

‡ Liebig's Annalen, cxliii, 156.

§ Chemical News, xxiv, 148.

|| Jour. Am. Chem. Soc., xix, 936.

Garrigues' method of procedure was to add acid diammonium phosphate to a warm solution of zinc exactly neutralized with either hydrochloric acid or ammonia so that the weights of zinc ammonium phosphate and that of the diammonium phosphate added should be as one to five respectively, to heat until the flocky precipitate becomes crystalline and subsides, filtering off on asbestos, drying at 100° C. and weighing preferably, although the residue may be ignited without loss, since the filtration is made on asbestos in a perforated crucible. Langmuir* modifies the method by destroying with dilute acetic acid any free ammonia that may be left in the solution after boiling.

In the work that follows, in which an attempt was made to show what precipitate is formed from a solution of zinc by the action of a soluble phosphate, also what effect ammonium chloride has upon the precipitate, a solution of zinc chloride prepared as detailed below was employed. The pure zinc chloride of commerce was treated with zinc carbonate, filtered and precipitated with ammonium sulphide. This precipitate was boiled in a slight excess of hydrochloric acid until all the hydrogen sulphide was removed, and then was precipitated with sodium carbonate. After washing carefully until all the chloride was removed, the greater part of the carbonate was dissolved in sulphuric acid in slight excess, boiled with the remaining portion of the carbonate and filtered. This solution diluted to definite volume was standardized as sulphate by evaporating the solution to dryness in a platinum crucible and heating the residue.† The heating is carried on safely by so placing the platinum crucible in a radiator (consisting of a crucible and a triangle) that the bottom of the platinum crucible was held about one centimeter above the bottom of the outside crucible. Constant weights were obtained in successive treatment with a few drops of sulphuric acid and heating over the radiator. The results obtained in this manner were a trifle higher, though in fair agreement (when the nature of the carbonate process is taken into consideration) with determinations of the zinc in the solutions as oxide after precipitating with sodium carbonate with the usual precautions, filtering off on asbestos under pressure in a perforated platinum crucible, washing with distilled water, drying and igniting. Results are given in Table II showing the amount of zinc sulphate found in five different portions each of forty cubic centimeters of the solution of zinc sulphate, and, for comparison, the results of determinations as zinc oxide by the carbonate processes are included.

* Jour. Am. Chem. Soc., xxi, 115.

† Rose-Finkener Analytische Chemie, 6^{te} Auflage, vol. ii, 117.

TABLE II.

ZnSO ₄ found in 40 ^{cm} ₃ of solution. gram.	Mean value of ZnO corresponding to ZnSO ₄ in 40 ^{cm} ₃ of solution. gram.	ZnO found in 40 ^{cm} ₃ of solution by precipitation as the carbonate. gram.
0.5386	0.2712	0.2691
0.5385		0.2685
0.5387		0.2711
0.5387		
0.5390		

Definite portions of the solution of zinc sulphate were carefully drawn from a burette into a platinum dish, heated and treated with ammonium phosphate until the solution turned red litmus paper blue. The whole was heated until the flocky precipitate became crystalline and fell to the bottom of the dish. The solution after standing as recorded in section A of the table was filtered off on asbestos under pressure in a perforated platinum crucible, and the precipitate was washed with distilled water, dried, ignited and weighed. The filtrate in each case, as in all following cases, was tested for zinc with sulphuretted hydrogen. The results recorded in section B of the table were obtained in the same manner as those of section A, with microcosmic salt substituted for the ammonium salt as the precipitant. The results are below the theory for the pyrophosphate, but no appreciable amount of zinc appeared in the filtrates. Neither ammonium phosphate nor ammonium sodium phosphate seems to precipitate the ideal ammonium zinc phosphate under these conditions; and the time of standing appears to be without effect.

The results recorded in section C were obtained by precipitating the warm solution of the zinc in presence of large amounts of ammonium chloride by adding microcosmic salt until the solution was alkaline to litmus. From these results it seems that the presence of ammonium chloride is essential for the conversion of the zinc phosphate precipitated by hydrogen sodium ammonium phosphate to the ammonium zinc salt. As a matter of fact the solutions employed by Guyard and those in which estimations are made by practical workers do contain ammonium chloride formed in previous steps of the analysis. The proportion of zinc to phosphate suggested by Garrigues—1:5—is the amount of soluble phosphate necessary to turn red litmus blue after the zinc is precipitated. In order to find out whether the presence of so large an amount of the soluble phosphate is necessary in presence of ammonium chloride, the solution of zinc sulphate was precipitated in presence of the necessary amount of ammonium chloride by the microcosmic salt, in small excess above the equivalent of

the ammonium phosphate, and the solution was made just ammoniacal to litmus with a few drops of dilute ammonia both before and after heating to convert it to crystalline condition. Experiment (15) shows that precipitation is not complete under these conditions. The zinc left in the solution was precipitated at once as sulphide, and estimated as the oxide, after dissolving in hydrochloric acid and precipitating with sodium carbonate. In (16) of the table the first filtrate was treated with an excess of microcosmic salt, and boiled. Another portion of the ammonium zinc phosphate was precipitated, and was filtered off and estimated. No zinc was found by sulphuretted hydrogen in the second filtrate.

TABLE III.

$Zn_2P_2O_7$ corresponding to $ZnSO_4$.	Found.	Error.	Error in terms of Zinc.	$Zn_2P_2O_7$ correspond- ing to Zn left in the filtrate.	$(NH_4)_3PO_4$.	NH_4Cl .	Time of stand- ing. hours.
Taken. gram.	gram.	gram.	gram.	gram.	gram.	gram.	
A							
(1) 0.6355	0.6206	0.0149—	0.0060—	trace	3.13	----	1½
(2) 0.6355	0.6254	0.0101—	0.0040—	trace	3.13	----	16
(3) 0.6355	0.6300	0.0055—	0.0022—	trace	3.13	----	16
B							
$HNaNH_4PO_4$.4H ₂ O							
(4) 0.6355	0.6271	0.0084—	0.0034—	trace	4.47	0.5	1
(5) 0.6355	0.6256	0.0099—	0.0040—	none	4.47	0.5	20
C							
(6) 0.6355	0.6285	0.0070—	0.0028—	none	4.47	10	½
(7) 0.6355	0.6304	0.0051—	0.0020—	none	4.47	10	¾
(8) 0.6355	0.6295	0.0060—	0.0024—	none	4.47	10	2½
(9) 0.6355	0.6335	0.0020—	0.0008—	none	4.47	10	16
(10) 0.6355	0.6381	0.0026+	0.0010+	none	4.47	20	½
(11) 0.6355	0.6379	0.0024+	0.0009+	none	4.47	20	2
(12) 0.6355	0.6386	0.0031+	0.0012+	none	4.47	20	½
(13) 0.6355	0.6393	0.0038+	0.0014+	none	4.47	20	½
(14) 0.6367	0.6355	0.0012+	0.0005+	none	4.47	30	16
D							
(15) 0.6355	0.6172	0.0183—	0.0072—	0.0108	0.894	20	3
(16) 0.6355	I 0.6227 II 0.0040	0.0098—	0.0039—	none	I 0.894 II 3.576	20	½
E							
(17) 0.6355	0.6270	0.0085—	0.0034—	none	4.47	----	3
(18) 0.6355	0.6125	0.0230—	0.0093—	0.0148	4.47	----	18
(19) 0.6355	0.6303	0.0052—	0.0021—	0.0020	4.47	10	18

From the results it seems obvious also that an excess of the soluble phosphate is necessary to complete the precipitation of the zinc as the ammonium zinc phosphate instead of partly ammonium zinc phosphate and partly tribasic phosphate.

In section E of the table are recorded results where the precipitation was made in presence of an excess of the precipitant either alone or in presence of ammonium chloride, the solution being made faintly acid to litmus with acetic acid, according to the manner in which Langmuir recommends to conduct the precipitation. All the results by the method are low. The condition of the ammonium zinc phosphate most nearly approximating to the ideal is obtained as shown in (9) to (14) by precipitating in presence of ammonium chloride in large amount. Microcosmic salt is added until the solution containing the ammonium salt is alkaline and the whole is heated until the mass subsides in crystalline condition. The amount of ammonium chloride should be twenty grams if the filtration is to be made as soon as the solution cools. One-half the amount will do if the liquid stands a number of hours. Larger amounts tend to give a salt too rich in ammonia. The time of standing seems to be a less important factor than either the excess of microcosmic salt or ammonium chloride.

The Ammonium Cadmium Phosphate.

According to S. Drewsen* the cadmium ammonium phosphate is precipitated by allowing a solution of cadmium sulphate to stand twenty-four hours with ammonium phosphate. It is very soluble both in acids and alkalis. No further preparation of this seems to have been recorded. For the work on this salt to be given below, made with reference to determining the constitution of the salt by hydrogen sodium ammonium phosphate, the effect of ammonium chloride in the precipitation, and the value of the salt for quantitative work, the solution of cadmium chloride employed was prepared as follows: A solution of cadmium sulphate acidulated with hydrochloric acid was precipitated with sulphuretted hydrogen, filtered and washed, and the precipitated sulphide was dissolved in hydrochloric acid and filtered from possible traces of copper and lead. The solution of the sulphide in hydrochloric acid was boiled until all the sulphuretted hydrogen was expelled, and filtered on asbestos in a perforated crucible of platinum under pressure. The cadmium in the filtrate precipitated with ammonium carbonate in excess was washed free from chloride, dissolved in hydrochloric acid and diluted to definite volume. It was standardized as oxide† after precipitating with sodium carbonate with the necessary precautions.

The standard solution of cadmium chloride was drawn carefully from a burette into a platinum dish, and, while hot, was precipitated by adding hydrogen sodium ammonium phosphate

* Gmelin-Kraut, 6^{te} Auflage, iii, 74.

† Browning, this Journal, xlv, 280.

until the solution was alkaline to litmus. After heating until the solution became crystalline, the whole stood three hours in case of (1) of the table and sixteen hours in case of (2) and (3), before filtering. In experiments (4) to (12), inclusive, recorded in the table, precipitation was made in the same manner as in (1) to (3) in presence of varying amounts of ammonium chloride, and the precipitates were filtered after standing as stated below in the table. It is clear from the results that the cadmium separates out completely on long standing only. Moreover, the ideal condition of the ammonium cadmium phosphate is obtained only when an abundance of ammonium chloride is present; but large amounts of ammonium chloride

TABLE IV.

	Cd ₂ P ₂ O ₇ corresponding to CdCl ₂ .		Error in terms of Cadmium.	Cd ₂ P ₂ O ₇ corresponding to Cd found in the filtrate.		HNaNH ₄ PO ₄ 4H ₂ O.	NH ₄ Cl.	Time of standing.
	Taken.	Found.	Error.	gm.	gm.	gm.	gm.	hrs.
(1)	0.6972	0.6201	0.0771—	0.0434—	0.0059	4.5	----	3
(2)	0.6972	0.6135	0.0837—	0.0471—	none	4.5	----	16
(3)	0.6972	0.6134	0.0838—	0.0471—	none	4.5	----	16
(4)	0.6972	0.6792	0.0180—	0.0101—	trace	4.5	1	16
(5)	0.6972	0.6831	0.0141—	0.0079—	0.0113	4.5	10	2
(6)	0.6972	0.6976	0.0004+	0.0002+	trace	4.5	10	16
(7)	0.6972	0.6969	0.0003—	0.0002—	trace	4.5	10	18
(8)	0.6972	0.6962	0.0010—	0.0006—	trace	4.5	10	16
(9)	0.6972	0.6891	0.0081—	0.0045—	0.0191	4.5	20	16
(10)	0.6972	0.6972	0.0000	0.0000	trace	4.5	20	16
(11)	0.6972	0.6942	0.0030—	0.0016—	trace	4.5	20	16
(12)	0.6972	0.6737	0.0235—	0.0132—	0.0304	4.5	30	16
(13)	0.6972	0.5655	0.1317—	0.0741—	0.1378	4.5	30	16
(14)	0.6972	0.6922	0.0050—	0.0023—	0.0088	4.5	10	16
(15)	0.6972	0.3209	0.3763—	0.2117—	0.2449	4.5	----	16

dissolve this salt. In (14), where ammonia was added after precipitation was complete, the salt dissolved somewhat; also in (15), where the solution was left faintly acid with acetic acid, a large part of the salt was dissolved. These weights of cadmium dissolved in the filtrate were obtained by treating the filtrates with sulphuretted hydrogen, dissolving the sulphide in nitric acid, and weighing as oxide after precipitating with sodium carbonate.

The ammonium cadmium phosphate is obtained in ideal condition by precipitating with microcosmic salt in presence of 10 grms. ammonium chloride in a total volume of 100^{cm} to 150^{cm}—shown in (6), (7) and (8)—filtering after standing some time. On drying and igniting the pyrophosphate is left. Very large amounts of ammonium chloride—30 grms.—dissolve the salt, and seem to tend to cause the formation of a

phosphate too rich in ammonia. Either acid or ammonia in small amount dissolves the salt, as is shown in (14) and (15).

The results of this investigation as to the analytical application of the double ammonium phosphates of beryllium, zinc, and cadmium may be summarized briefly as follows: It is impossible to estimate beryllium with accuracy as the pyrophosphate obtained by igniting the double ammonium phosphate precipitated from beryllium solutions by microcosmic salt or ammonium phosphate in presence of ammonium chloride. In presence of the proper amount of ammonium chloride (10 gm. to 20 gm. in 100^{cm}³–200^{cm}³ of liquid) zinc ammonium phosphate can be obtained in the ideal condition, which on ignition yields the pyrophosphate. This method may serve, therefore, for the accurate estimation of zinc.

Cadmium may be estimated with accuracy as the pyrophosphate if the precipitate by microcosmic salt in the nearly neutral solution containing ammonium chloride in the proportion of ten grams to one hundred cubic centimeters is allowed to stand several hours before filtering. In this way all cadmium separates out from the solution as a beautiful crystalline mass of cadmium ammonium phosphate of ideal constitution. The conditions must, however, be preserved with care; there must be no excess of ammonia, no free acid, and no excess of ammonium salt beyond the quantity indicated, while that amount is necessary.

ART. XXII.—*Separation of Iron from Chromium, Zirconium, and Beryllium, by the Action of Gaseous Hydrochloric Acid on the Oxides*; by FRANK STUART HAVENS and ARTHUR FITCH WAY.

[Contributions from Kent Chemical Laboratory of Yale University—LXXXVII.]

It has been shown in a former paper from this laboratory* that iron oxide may be completely volatilized as chloride by a strong current of hydrochloric acid gas acting at a temperature of 450–500°, and also that the addition of a little free chlorine to the gaseous hydrochloric acid renders this action complete at lower temperatures, 180–200°, without the danger of error arising from the liability of ferric chloride to dissociation, or from deficiency of oxidation in the oxide treated, or mechanical loss due to too rapid volatilization. It has also been shown that this reaction can be employed for the separation of iron and aluminum, taken as the oxides, and its application to the separation of iron from other metallic oxides has been suggested.

The oxides of chromium, zirconium, and beryllium, like aluminum oxide, are not acted upon by a current of dry hydrochloric acid gas at the temperatures before mentioned, and these oxides also can be entirely freed from iron by this reaction, as the experiments to be described will show. The procedure was the same in each case and analogous to that employed for the separation of iron from aluminum. A mixture of a weighed portion of one of these oxides with a weighed portion of ferric oxide, contained in a porcelain boat and placed within a roomy glass tube supported in a small combustion furnace, was submitted to the action of a dry current of hydrochloric acid gas and chlorine generated by dropping sulphuric acid upon a mixture of strong hydrochloric acid, common salt, and a small amount of manganese dioxide. The gas was admitted at one end of the combustion tube and passed out at the other through a water trap, while the required temperature, from 200°–300°, was maintained by regulating the various burners of the furnace. The time of action varies somewhat with the condition of the oxide to be volatilized, and the temperature, generally an hour's heating at 200°, proves sufficient for the complete removal of 0.1 gram of iron. At higher temperatures the action is more rapid; but the lighter oxide, the beryllium especially, is liable to mechanical loss through the too rapid volatilization of the iron, as experiment (17), where a temperature of 500° was used, will show. It is

* Gooch and Havens, this Journal,

better, therefore, to use lower temperatures, raising the heat for a few minutes when the action is apparently complete to ensure the removal of the last traces of iron. Tests showed the residual oxides from which the ferric oxide had been removed in this manner to be entirely free from iron.

Exp.	Fe ₂ O ₃ taken. grams.	Cr ₂ O ₃ taken. grams.	Cr ₂ O ₃ found. grams.	Error. grams.
1	----	0.1008	0.1008	0.0000
2	0.1007	0.1006	0.1006	0.0000
3	0.1007	0.1000	0.1002	+0.0002
4	0.1010	0.1005	0.1003	—0.0002
5	0.1019	0.1006	0.1005	—0.0001
6	0.2007	0.1003	0.0999	—0.0004
		ZrO ₂ taken. grams.	ZrO ₂ found. grams.	
7	----	0.1516	0.1516	0.0000
8	0.1053	0.1010	0.1010	0.0000
9	0.1204	0.1519	0.1523	+0.0004
10	0.1236	0.1516	0.1517	+0.0001
11	0.2150	0.1517	0.1519	+0.0002
		BeO taken. grams.	BeO found. grams.	
12	----	0.1309	0.1311	+0.0002
13	----	0.1285	0.1285	0.0000
14	0.0997	0.0456	0.0457	+0.0001
15	0.1045	0.1099	0.1099	0.0000
16	0.1215	0.1080	0.1081	+0.0001
17	0.1510	0.1305	0.1290	—0.0015
18	0.2030	0.1081	0.1083	+0.0002

The separation of iron from chromium, zirconium, and beryllium by this method is obviously complete within very satisfactory limits of error.

ART. XXIII. — *An Albertite-like Asphalt in the Choctaw Nation, Indian Territory* ;* by JOSEPH A. TAFF.

History of its development.

IN the fall of 1897, while surveying the southern part of the McAlister Quadrangle in the Indian Territory, coal-like stringers interstratified with greenish shale were discovered in McGee Creek Valley. The stringers were one foot and less in thickness, and in places were intermingled with fragments of shale of the same nature as that in the wall rock. The shale upon both sides was of the same kind, was not carbonaceous, and was not of the nature of fire-clay as is usually found in contact with coal. The relation between the carbonaceous substance and the shale did not attract especial comment, since the rocks were nearly on edge and supposed to be in a faulted zone.

On working farther south in Impson Valley, T. 1 S., R. 15 E., an exposure of the same coal-like mineral was found cropping out in Ten Mile Creek in the same formation as on McGee Creek. The bed was partially concealed by water, but by good authority it was reported to be four feet thick. Still farther south on the west side of Impson valley, near the south side of T. 1 S., R. 15 E., the same mineral had been prospected and exploited on a small scale. A shaft twenty feet in depth had been sunk upon its outcrop where it was reported to be 25 feet thick and almost upon edge. The shaft was full of water at the time and the coal concealed.

The deposit was discovered by prospectors in 1890, exploited in 1892 and a little later abandoned because of the steep dip and friability of the product. Specimens were collected by the writer and submitted with a series of bituminous coals from the McAlister region for proximate analysis. These analyses were made by Dr. W. F. Hillebrand, and are placed here for comparison.

	Water.	Volatile Combustible Material.	Fixed Carbon.	Ash.	Sulphur.	Phosphorus.
Albertite.	·25	42·33	55·97	1·45	1·47	0·00
Coal.	1·63	38·27	55·15	4·84	1·51	0·014

(Hartshorne)

The low percentages of water and ash in the albertite are the only features that would attract attention. On applying a flame to a fragment of the mineral it softens, disintegrates and ignites, burning for a short time after the removal of the flame. This, however, connected with the fusibility and friability of the mineral, indicates strongly that it is not a true coal.

* Published by permission of the Director of the U. S. Geological Survey.

On returning to the field in 1898, a second inspection of the three localities of the mineral was made. It was found that Mr. Geo. D. Moulton had leased the lands including the prospects in Impson Valley. The mine near the south side of T. 1 S., R. 15 E., was being operated. Entries were made along the strike for 100 feet to both the foot and hanging walls. The mineral was found to form a vein, cutting folded green clay shale and striking nearly north and south and approximately parallel with the general trend of the rocks. The vein dips about 70 degrees east. The shale at both foot and hanging walls has been crushed so that its structure is destroyed and slickensided surfaces extensively developed. Two sets of joint planes bearing respectively northeast and northwest intersect the vein. The vein material, also, in some of the joints is striated, showing that there has been movement along such faces since the solidification of the mass.

The development of systems of joints in the vein intersecting approximately at 45 degrees to the face of the wall would indicate crushing pressure perpendicular to such faces while the mineral was in a solid or semi-solid state. The whole of the vein at the time when excavations had been made in it to a depth of about 30 feet showed indications of apparent crushing.

Mr. Moulton, the owner and operator of the mine, reports that at a depth of about 35 feet the vein for 12 feet inward from the foot wall has changed in structure. The specimens submitted by him, though small, show a compact mass with a smooth conchoidal fracture in contrast to the friable product with hackly surface found in the upper part of the vein and in the entire body of the vein to a depth of more than 30 feet.

Samples were collected from the face of the working 30 feet beneath the surface and submitted to Dr. Wm. C. Day for complete analysis. I quote the essential part of Dr. Day's report of the analysis. Duplicate tests were made in the determination of specific gravity, of solubility, and in the chemical analysis.

"Report on the hydrocarbonaceous material supplied by Mr. Joseph A. Taff of the U. S. Geological Survey.

The material is extremely brittle, pulverizing almost at a touch; it takes fire readily. It shows no sign of conchoidal fracture. Heated in a tube it does not melt but softens and gradually cokes progressively without becoming liquid at any one time.

Distillation of the asphalt from a retort showed that it does not entirely melt at any one time but softens and decomposes

simultaneously like a coal. The distillate is dark red by transmitted light and shows a decided green fluorescence. For sake of comparison a quantity of soft coal used for making coal gas and obtained from a gas works was distilled. This gave a more tarry distillate but less in amount for equal weights of material. The odor of the distillate from the coal was markedly different from that from the asphalt; it lacked also the green fluorescence of the distillate from the asphalt. The coal was practically insoluble in carbon disulphide, while the asphalt was soluble to the extent of over 35 per cent.

The material, all things considered, resembles albertite more than any other of the asphalt substances, but it differs from it too in certain respects. For the sake of comparison the data contained in Dana's Mineralogy on albertite are placed here side by side with the corresponding data pertaining to the material supplied by Mr. Taff.

Albertite.		Mr. Taff's material.	
Specific gravity 1.097.*		Specific gravity 1.175.	
Color, jet black.		Color, jet black.	
Softens a little in boiling water.		Does not soften in boiling water.	
In the flame of a candle shows incipient fusion.		In flame of candle shows incipient fusion and takes fire, burning for a short time after removing from the flame.	
Only a trace soluble in alcohol.		Only a trace soluble in alcohol.	
4% soluble in ether.		5.34% soluble in ether.	
30% soluble in turpentine.		Almost insoluble in turpentine.	
Per cent. of carbon as found by Wetherill.....	86.04	Per cent. carbon	86.57
Per cent. hydrogen (Wetherill).....	8.96	“ hydrogen	7.26
“ nitrogen (Wetherill).....	2.93	“ nitrogen	1.48
“ nitrogen (Day) 1.84		“ sulphur	1.38
“ sulphur (Wetherill).....	trace	“ oxygen	2.00
“ sulphur (Day).....	0.17	“ ash	1.31
“ oxygen (Wetherill).....	1.97		
“ ash (Wetherill).....	0.10		

Of the differences between albertite and the Taff asphalt the contrast in the solubility in turpentine is perhaps the most striking.

While the material submitted by Mr. Taff resembles a coal in the way it softens and decomposes under the influence of

* I find for Nova Scotia albertite sp. gr. 1.074 at 20° C.

heat instead of entirely melting as asphalts generally do, the distillation products are markedly different from those of coals in abundance, in fluorescence, and in odor.

As the result of examining the analytical figures given in Dana's *Mineralogy* for a long list of coals, I can find none which even approximate those found for the material in question. The solubility in carbon disulphide classes the material with the asphalts, rather than with the coals. The analytical figures and the solubility show that the material resembles albertite from Nova Scotia more than any other of the asphalt-like bodies which have thus far been investigated."

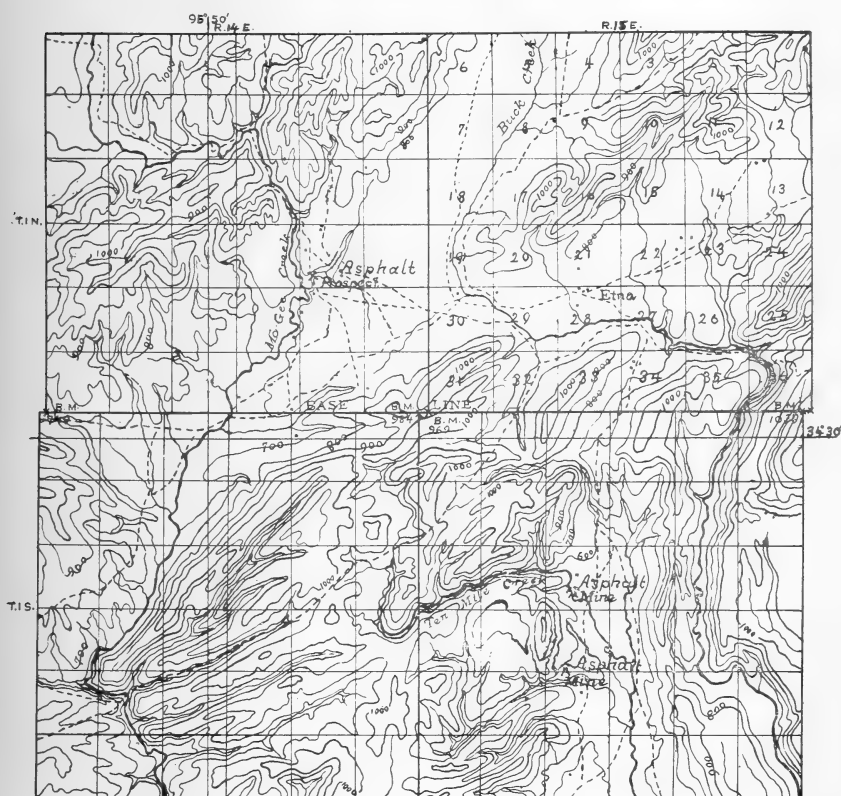
Geology of Associated Rocks.

The map will show the general topographic character of the country as well as the located occurrences of albertite. It also gives the township land surveys which substitutes a scale for any location. The mapped district lies in both the McAlister and the Antlers Quadrangle. The parallel of latitude, $34^{\circ} 30'$, is the line between them, the McAlister being on the north. The contours mark elevations above the sea level and are at intervals of 100 feet.

The topography of the country is characteristic of the Ouachita mountain system in the Indian Territory to which it belongs. It is a system of rugged and generally parallel stony hills and small mountains which rise to elevations of from a few hundred to a thousand and even more feet above nearly level plain-like valleys which are often several miles wide and many miles long. These plain-like valleys are governed by and limited to the outcrop of shales and other associated friable rocks. By observing the map a wide valley may be noted extending from McGee Creek in the north part of T. 1 S., R. 14 E. northwestward to Buck Creek, where it is divided by the Jack Fork Mountains. There is another such valley known locally as Impson Valley in the center T. 1 S., R. 15 E., in which the asphalt mines are located. The mountains, hills and all elevated lands are rugged and are held up by many beds of hard sandstone whose edges are exposed. The streams in the plains have little or no valleys of their own. Their channels, also, are little more than ditches cut in the soil and soft rock. The streams which flow in or across the hilly country are confined to narrow and often deep gorges or valleys.

The structure of the rocks, especially that of the shales, is hard to interpret. Besides having been folded and faulted to an extent difficult of appreciation, the beds are almost entirely concealed by soil and rock debris. It has been clearly determined, however, that the beds have been folded along lines

northeast and southwest, then overturned towards the northwest and, in many places, faulted. Especially where shales are involved the crushing and faulting has been very extensive. Three lines of faulting bearing northeast and southwest and having displacements of many hundred feet, extend along the southeast sides of the group of hills through the center of T. 1 N., R. 14 E., of the Jack Fork Hills in the center of T. 1 N., R. 15 E. and of the hill in section 3, T. 1 N., R. 15 E. respectively. The latter two lines of faulting extend from the ends of the hills southwestward into the plain toward the albertite exposures.



Map to show location of asphalt mines in Choctaw Nation.

Another zone of faulting extends from the plain nearly two miles east of Etna bearing southwestward, crossing the center of the south side of T. 1 N., R. 15 E. thence nearly due south along the west side of Impson Valley. The albertite mines of this valley are located along this fractured zone. The north

end of this valley, in Section 10, T. 1 S., R. 15 E. is anticlinal and the rocks along the east side of the valley dip normally toward the east. On the west side, however, the older shales which contain the albertite are thrust upward against the younger sandstones of the hills.

The geology, were it not for the complications of structure, would be simple. For all purposes necessary here, however, the problem of the geology may be briefly stated. The shales which lie in the plains and wide valleys noted above, and which contain the albertite, are the oldest known in this district. Their thickness is difficult to determine, though it is estimated to be several thousand feet. They are composed of greenish and bluish clay shales, sandy shale and greenish friable sandstone. Thin beds of black siliceous slate have been noted in the upper part of this body of shale.

All the thick sandstones which form the hills and ridges lie above the shales. The aggregate thickness of these sandstones is estimated also to be several thousand feet. Beds of limestone which have been found to occur just above the sandstone formation contain fossils of Ordovician age. Hence it is concluded that the sandstones and the shales which contain the albertite are of Ordovician age or older.

Conclusions.

The mineral, in both its physical and chemical properties, is shown to be an asphalt and more closely related to albertite than to any other known asphalt substance. Indeed its only variation from albertite of any moment is its solubility in turpentine. The friability and fracture of the sample submitted for analysis is, without much doubt, due to its structural condition produced by pressure after solidification. The product occurs as veins or dikes filling fissures along zones of thrust faulting. It occurs in shales of, at present, unknown age.

The quantity of this asphalt can be conjectured only. As far as known it occurs in thin stringers, in a vein about 4 feet thick, and in a vein about 25 feet thick. The surface of the shale containing the product is worn down in valleys and concealed by soil or overwash so that the asphalt is known only so far as prospected. From the manner of its occurrence in fissures produced by fracture, where it has suffered probably great pressure, the vein is supposed to vary in thickness and in longitudinal extent and may descend to any reasonable depth.

ART. XXIV.—*Notice of a new Meteorite from Murphy, Cherokee Co., N. C.*; by HENRY L. WARD, Rochester, N. Y. With Plate IV.

IN May of the present year we received word from Mr. W. B. Lenoir that he had what he supposed to be a meteorite that he desired to sell. Upon request he forwarded it to us; and a superficial glance at the well-pitted surface was sufficient to determine that it was a siderite.

Under date of May 25th, Mr. Lenoir writes: "It was ploughed up or washed out in a field in Cherokee Co., N. C., five miles from Murphy. From the location [where] found I think it must have been washed out by some of the immense rains which fell in that section last winter. . . . The small piece enclosed with the larger one was broken off when I purchased it. . . . The stone [iron] I understand was found about six weeks ago." Later he writes: "In answer to yours of June 10, asking how the meteorite was broken, will say that I did not break the meteorite. The man who first showed me the piece said that they attempted to cut it with a cold chisel and did not succeed. By some means (I think he said) they cut around it and then either with a blow or by prizing broke it off. . . . He said he had a 'hell of a time' breaking it."

As was to be expected, this meteorite adds another to the great majority of siderites the date of whose fall is unknown.

Fig. 1, Plate IV, shows the iron with the broken piece set in place so as to give the original form. Its height is 23.5^{cm}. A rectangle drawn about the base upon which it stands measures 13.4×11.5^{cm}. The weight of the iron was 7753 grams (17 lbs. 1½ oz.), of which the broken end weighed 808 grams. Another photograph of the entire iron was taken to show the remarkably sharp angle formed by the left hand edge and the side opposite to that shown in fig. 1; but a defect in the plate rendered this photograph unusable. Fig. 2, showing end views of both pieces from the broken surface, gives something of this angularity, which was rather more marked lower down. In some of the larger sections cut across the iron this angle is rather more acute than a right angle, as this side is somewhat concave, and the edge is very sharp. These two surfaces are less deeply pitted than the one shown in the figure; and convey the impression that the meteorite in hand is but a fragment of a larger one that broke not far above the earth. Had it traveled far since dividing we would expect the angles to be rounded. An examination of the crust fails to give any evidence for or against this theory. Flow lines, if they ever

existed, have been removed by weathering and the oxidized crust appears equally thin on all sides. The fact that the edges of the mass are approximately parallel to the lines of crystallization is only in accordance with what has been shown to be common to siderites in general.

The square fracture is an interesting feature that I believe to be quite unusual in iron meteorites. Its surface is nearly a parallelogram 4.8×3.3 cm, with one of the shorter sides surmounted by a triangle 3.5 cm in height; giving a surface of approximately 21.5 sq cm. One side shows that it has been cut by a cold chisel to a depth of about 2 mm. The rest of the face is a clean straight break with a hackly surface. This is shown on the larger mass in fig. 2.

The etched surface presents two main series of lines enclosing rhombs having the angles 161.2 and 18.8 ; other lines crossing these produce all the figures compatible with the twinning about a cube with the exception of a single line, which probably exists but which I have been unable to find.

Under the microscope each higher power up to about one hundred diameters reveals lines not seen with lower powers. That the series of lines giving the angles above mentioned are the primary ones, is indicated by the fact that the lines of fracture on the broken face have followed these. On a section cut at right angles to these, the lines apparent to the eye give decidedly larger figures; but under the microscope this distinction disappears.

The Neumann lines were visible in the photograph of the etched end shown in fig. 2; but are entirely lost by the screen used in making the half tone; consequently we introduce a print directly from an etched section of the iron, fig. 3, which under a hand lense should show the lines fairly well.

Troilites appear in all the sections; but are in most cases of very small size. The largest one that appears measures 9×13 cm in diameter. It is interesting to note that the Neumann lines are materially flexed immediately about some of the troilites: indicating that they existed in a plastic condition during the growth of the troilites.

Daubreelite, in unusually large masses, occurs in two of the slices; both as veins crossing the troilites and as solid masses at the sides. The largest mass measures, on its two nearly rectangular faces, 5.5 and 5 mm; the other sides being formed by a segment of the nearly circular border of the troilite within which it has formed.

An analysis of the iron has not yet been made.

Unfortunately the more euphonious title "Cherokee County" has already been applied to the Losttown, Cherokee Co., Ga., siderite, and we are forced to adopt the less pleasing one of the town near which it was found, *Murphy*, as the name for this meteorite.

ART. XXV.—*On the Separation of Alumina from Molten Magmas, and the formation of Corundum*; by J. H. PRATT.

SOME interesting problems have arisen, in recent years, regarding the differentiation of igneous magmas upon cooling. It has been the author's privilege during the last three years to study in the field various occurrences of corundum, spinel and chromite in peridotite rocks, and in some recent papers* the igneous origin and the chemical composition of these minerals have been discussed by him. It is the intention in this paper to give those field observations that have a theoretical bearing upon the separation of these minerals from a molten magma and more especially of the alumina.

The results of the elaborate studies that have been made by Vogt,† Morozewicz,‡ Lagorio§ and others upon the artificial formation of minerals in molten magmas, have been verified by observations upon the occurrence of the same minerals in nature that have also separated out from molten magmas.

The separation of alumina is well illustrated in nature in the occurrence of corundum, spinel and chromite in the rocks of the peridotite group. Of these rocks, the most common one containing these three minerals is dunite, consisting almost entirely of chrysolite or its alteration product, serpentine. In the analyses of the dunite rocks, they show either a trace or very small percentage of alumina or chromic oxide or even none; and in the analyses of other peridotites than dunite, the same usually holds true for amounts beyond those required in the composition of the normal minerals that compose these rocks.

The peridotite localities that have been examined by the author are all located in the western part of North Carolina, and at these various localities the following phenomena have been observed:

1. Peridotite rocks containing small particles and grains of chromite but no corundum or spinel.
2. Peridotite rocks containing deposits of chromite (which upon analysis showed a variable per cent of alumina and magnesia), but no corundum or spinel.
3. Peridotite rocks containing chromite, corundum and spinel.

* This Journal, vol. vi, July, 1898, p. 49; *ibid.*, vol. vii, April, 1899, p. 281, and Trans. Am. Inst. Mining Eng., vol. xxix, 1899.

† Zeitschr. für Prakt. Geol., Nos. 1, 4 and 7, 1893.

‡ Zeitschr. für Kryst., vol. xxiv, p. 281, 1895, and Tschermak's *Min. u. Petrog. Mittheilungen*, Bd. xviii. H. 1-2-3, pp. 1-90 and 105-240, 1898.

§ Zeitschr. für Kryst., vol. xxiv, p. 285, 1895.

4. Peridotite rocks containing chromite and corundum, but no spinel.

5. Peridotite rocks containing corundum and feldspar.

1 and 2. In the analyses of the chromites that have come under the author's notice, all but two show the presence of alumina and magnesia in varying amounts. In some of them the percentage of alumina and magnesia is very large and where in the ordinary chromite the formula may be represented by $9(\text{FeO} \cdot \text{Cr}_2\text{O}_3)$, $(\text{MgO} \cdot \text{Cr}_2\text{O}_3)$, $2(\text{MgO} \cdot \text{Al}_2\text{O}_3)$; at one locality near Webster, Jackson County, a chromite (*mitchellite*), was found which had the formula $(\text{FeO} \cdot \text{Cr}_2\text{O}_3)$, $(\text{MgO} \cdot \text{Cr}_2\text{O}_3)$, $2(\text{MgO} \cdot \text{Al}_2\text{O}_3)$. Thus when there is considerable chromite found in these rocks, there is usually no, or at most but a trace of corundum present, and from what has been said above regarding the analyses of chromite, it would seem to be the case that when there is but little alumina and only a small excess of magnesia in peridotite magmas, containing considerable chromic oxide, that they unite to form the spinel molecule which instead of separating out independently as the mineral spinel, enters into combination with the $\text{FeO} \cdot \text{Cr}_2\text{O}_3$ molecule in the mineral chromite.

3. At a few of the peridotite localities both corundum and spinel have been found, as at the Corundum Hill Mine, where a fine-grained, almost black spinel occurs through which is scattered particles and masses of corundum; and at the Carter Mine near Democrat, where there is a great abundance of corundum and a green black spinel. In peridotite magmas of this type, it would seem that there has been an excess of magnesia present which has united with a portion of the alumina present to form the molecule $\text{MgO} \cdot \text{Al}_2\text{O}_3$, which separated out as spinel. The remaining portion of the alumina formed corundum.

Undoubtedly there is a strong affinity between magnesia and alumina which tends to form the spinel molecule; but in these peridotite magmas, it is only the excess of magnesia over that required for the normal magnesian silicates that has united with the alumina. Except alteration products there are no alumina-magnesia silicates found in these rocks, showing that in magmas of this type there is no tendency for the alumina to unite with the magnesia in forming double silicates.

4. At most of the peridotite localities there has been no spinel at all observed, but there is often a considerable quantity of corundum found. The chromite at all these localities shows the presence of a certain percentage of alumina and magnesia. Thus the small excess of magnesia unites with a definite amount of the alumina, but instead of separating out as spinel, it separates out in the chromite molecule as previ-

ously mentioned. The greater part of the alumina separates out as corundum.

5. In a number of these peridotite formations feldspar has been found which is undoubtedly one of the original minerals of the rock and not a secondary product.

At the Cullakeenee Mine, Buck Creek, Clay County, there is, at one of the contact corundum veins, a large amount of feldspar and hornblende which have separated out with the corundum: again at the Bad Creek Mine, Sapphire, Jackson County, the corundum is found associated with feldspar and biotite mica. In both places they are lime-soda feldspars, and this occurrence of feldspar and corundum in a peridotite rock indicates that the molten magma contained some of the alkali and alkali earth oxides, as Na_2O , K_2O and CaO , and that a portion of the alumina united in the formation of the feldspar molecule and that the rest of it separated out as corundum. In a magma of this type, there is present a large amount of magnesia which forms the magnesian silicates but apparently has no tendency to unite with the alumina to form the spinel molecule; but on the other hand the small amount of the alkalies and alkali-earth oxides do unite with a definite amount of the alumina to form the feldspar molecule. This again would seem to indicate, that in the presence of a certain amount of the alkali and alkali-earth oxides and silica that if there is enough silica present to unite with these oxides and the magnesia, there is no tendency for the magnesia to unite with the alumina to form any type of magnesia-alumina minerals.

Morozewicz* has recently described the formation of corundum from a number of magmas that were supersaturated with alumina. The supersaturated alumina-silicate magmas had the general composition $\text{MeO} \cdot m\text{Al}_2\text{O}_3 \cdot n\text{SiO}_2$ ($\text{Me} = \text{K}_2, \text{Na}_2, \text{Ca}$, and $n = 2-13$). In these magmas, on cooling, all the excess of alumina (over $m = 1$) separates out in the form of corundum crystals, this taking place when magnesia and iron were not present.

In these experiments, the silicates that were used to form the magmas were for the most part those of calcium, sodium and potassium. When alumina was present in them in excess of $m = 1$, it would separate out in the form of corundum; but when the magma was not saturated with alumina or m was equal to 1 or less, all the alumina was used up in the formation of double silicates. When magnesia was present, the excess of alumina united with the magnesia to form the mineral spinel, and if not enough magnesia was present to unite with all of

* Tschermak's Min. u. Petrogr. Mittheilungen, xviii, pp. 1-90 and 105-240, 1898.

the alumina, some corundum was formed. When there was an excess of silica, or n is greater than 6, the excess of alumina unites with the silica to form the mineral sillimanite and the over excess of alumina would separate out as corundum. When, however, magnesia and iron are present with the excess of silica and alumina, cordierite and spinel are the minerals formed.

From these experiments it would seem that where a magma is composed of silicates of the alkali and alkali-earth metals, sodium, potassium and calcium, that the alumina dissolved in this magma will to a certain point unite to form double silicates of alumina with these other bases; but when the ratio of alumina to these bases is greater than 1, the excess of alumina will separate out as corundum except when influenced as just described. Magnesia, it would seem, does not have as strong an affinity for the formation of silicates, and when present in the magmas, influences the separation of the alumina as a double salt of magnesia and alumina in the formation of the mineral spinel, or with an excess of both alumina and silica in the formation of the mineral cordierite.

In some earlier experiments, Morozewicz* has shown that alumina will readily dissolve in a molten magma having a composition approximately that of the basic magnesian rocks; and that upon cooling the alumina separates out as corundum and spinel.

There seems to be but little tendency for the alumina to unite with the magnesia to form the double silicates or with the magnesia alone to form the mineral spinel, $MgO.Al_2O_3$, except when there is an excess of MgO , when some spinel is formed, but the greater portion of the alumina separates as corundum. This would seem to show that the affinity of magnesia for silica in the formation of a silicate molecule is stronger than for alumina to form the aluminate molecule.

Summary.—From what has been observed in nature and from the experiments that have been made in the laboratory, it seems that the separation of alumina as corundum from molten magmas is dependent upon the composition of the chemical compounds that are the basis of the magma, upon the oxides that are dissolved with the alumina in the magma and upon the amount of alumina itself.

1. When the magma is a calcium-sodium-potassium silicate, no alumina held in solution by such a magma will separate out as corundum except when the ratio of the alumina to the other bases is more than 1:1 and the ratio of the silica is less than 6.

* Zeitschr. für Kryst., vol. xxiv, p. 281, 1895.

2. If magnesia and iron are present in the above magma, corundum will not form unless there is more than enough alumina to unite with the magnesia and iron.

3. When the magma is composed of a magnesium silicate without excess of magnesia, *all* the alumina held by such a magma will separate out as corundum.

4. Where there is an excess of magnesia in the magma just described, this will unite with a portion of the alumina to form spinel and the rest of the alumina will separate out as corundum.

5. Where there is chromic oxide present in a magma composed essentially of a magnesium silicate (as the peridotite rocks) and only a very little alumina and magnesia are present, these, uniting, separate out with chromic oxide to form the mineral chromite and no corundum or spinel are formed.

6. When peridotite magmas contain, besides the alumina, oxides of the alkalies and alkali-earths, as soda, potash and lime, a portion of the alumina is used in uniting with these oxides and silica to form feldspar.

7. There is a strong tendency for the alumina to unite with the alkali and alkali-earth oxides to form double silicates like feldspars, whether such silicates form the chief minerals of the resulting rock or are present only in relatively small amount. There is, however, but little tendency for the alumina to unite with magnesia to form double silicates when the magma is a magnesium silicate.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY AND MINERALOGY.

1. *Canada; Summary Report of the Geological Survey Department for the year 1898.*—Among the items of general interest in the report are the following :

“The aggregate value of the production of minerals in Canada during the year 1897, as finally corrected and published, is \$28,661,430, being an increase of about 27 per cent over that of the previous year. This is largely accounted for by the great development of gold mining, particularly in the Yukon district, the value of the gold produced being more than double that for 1896.”

The Director examined the North Saskatchewan gold district, where much interest is taken in the use of dredging machinery to gather the river gravels. He reports regarding the occurrence of the gold in the “Saskatchewan gravels,” that

“Gold in fine scales and particles, generally so minute as to require the employment of mercury in collecting it, is now known to occur on almost all the rivers running eastward from the Rocky Mountains, to the north of the International boundary, wherever these have been prospected. To the south of the Peace River, this gold, in any workable quantity, seems invariably to characterize a portion of the length of each of the rivers, giving out to the westward before the base of the Rocky Mountains is reached, and to the eastward along a less well defined line, but one probably due, in this case, to the local substitution of sand and clay banks and beds for the gravel bars of the upper and more rapid parts of the streams. The Peace River and the Liard, rising to the west of the Rocky Mountains proper, among rocks known to be auriferous, contain more or less gold throughout their lengths, or to points in their lower courses where the changed conditions of flow, above alluded to, render the collection of any minutely divided gold which they may still carry practically impossible. In other words, in these two rivers, and possibly also in some still farther to the north, a considerable part at least of the contained gold comes directly from their upper tributaries; while in the case of the Athabasca, the North Saskatchewan and other rivers farther to the south, the evidence at first sight appears to be entirely against the possible derivation of gold from the mountains to the westward.”

“The result of recent observations appears, therefore, to indicate that the gold found in the Saskatchewan and other rivers of the Northwest has come in part from several sources, but has been derived chiefly from the crystalline rock of the Laurentian axis or plateau to the eastward or north-eastward, from which it has been transported with the fragments of these rocks that now form so conspicuous a part of the ‘drift’ of the Great Plains.

The recognition in late years of the Huronian as a distinctly gold-bearing formation, in itself goes far to establish the correctness of the hypothesis originally advanced on this subject, as rocks of this formation occupy considerable areas of the Laurentian plateau."

In these gravel deposits, six miles above Edmonton, bones of *Elephas primigenius* or *Americanus*, and of *Ovibos moschatus* have been discovered.

The overthrust faults in the Cretaceous coal-bearing district of Crow Nest Pass, on the eastern side of the Rocky Mountains, lead to the expectation of finding coal beds of Cretaceous age below Paleozoic limestone.

This peculiarity in the structure is adduced as an explanation of the petroleum occurring in rocks of which the surface is of probable Lower Cambrian age—between Crow Nest and South Kootenay passes in the southern part of the Rocky Mountains.

The borings for petroleum at Athabasca Landing have been continued, but without practical success. Mr. Fraser explains the hindrance to attempts to reach the sources of the petroleum in his report as follows:

"The bore at Pelican River had been stopped at 820 feet owing to the striking of an immense flow of gas, which made it impossible to work while it continued to flow with such force. It was thought that by the spring of 1898 it would have exhausted itself sufficiently to permit further boring, and to this end the casing, 4½ inches in diameter, was left quite free and open to permit the escape of the gas. It was estimated that before a depth of 1000 feet was encountered the Devonian limestone would be pierced.

"Upon investigation in the early part of the present season, the flow of gas seemed to have very materially decreased; but upon operations being resumed, the seeming decrease was found to be in a great measure due to the closing up of the outlet at the bottom part of the casing by an asphalt-like mixture, composed of maltha, or petroleum tar, and sand. In fact, when boring operations were resumed on June 17th, the difficulty was found to be intensified by the accumulation of this asphalt-like maltha in the bottom of the bore.

"The rapid expansion of the gas produced a very low temperature, and this chilled and solidified the tar, or maltha, until it became as adhesive as wax. As the tools cut it loose the gas would carry it up through the bore, until from bottom to top it was almost one mass of sand and tar. The only way it could be extracted from the sand-pump was by heating the latter over a fire; even then very little could be got out at one time, it being so thick that it was almost impossible to force it up into the pump. I used different sorts of tools to cut it off the walls and clean it out, but the longer we worked at the bore the greater the quantity of tar accumulating on the sides of the casing and tools."

On the Pembina River in northern Alberta, Mr. McEvoy reports:

"Several outcrops of coal occur on the banks of the river, principally above the crossing. The coal has been on fire here years ago, and the overlying beds of clay and shale have fallen in, giving a very disturbed appearance to the locality. The white clay is partly burned to a pale red terra cotta. Half a mile above the crossing, on the east side, a seam of coal 17 feet 10 inches thick is exposed, of which the upper four feet is impure. On the opposite side there is a seam 13 feet thick, having four small partings of clay and carbonaceous shale, amounting in all to nine inches."

Dr. Adams in his study of the Grenville series in Monmouth reports important evidence of their sedimentary origin. He says:

"The study of the Grenville series in Monmouth showed beyond a doubt, that this series is a sedimentary one. It includes a great development of bedded white quartzites, evidently altered sandstones. The associated limestones also, that occur in heavy bands, and, as everywhere else in the Grenville series are in the form of white crystalline marbles, were in a few places along the line of the Irondale, Bancroft and Ottawa Railway, seen to hold little dark strings suggestive of remnants of the original limestone in a less altered condition. On this account, a careful search was made, which resulted in the discovery of two localities in which the limestone was almost unaltered, being very fine in grain and blue in color, and bearing a strong resemblance to the limestones of more recent formations. In such case the blue limestone is interstratified with the ordinary white coarse-grained marble of the Grenville series and passes into it, there being evidently portions of the limestones which have escaped metamorphism. These occurrences serve to dispose of any lingering doubts concerning the sedimentary origin of the limestone in question."

Silurian fossils were discovered about six miles from Canterbury station of the St. Andrews and Woodstock branch of the Canadian Pacific Railway, in a belt of rocks lying northwest of the granite area in western York. The rocks in question have hitherto been classified as Cambro-Silurian. They are partially altered gray slates. The fossils, according to Dr. Ami, indicate uppermost Silurian.

Along the shore of Grand Manitoulin Island, Lake Huron, a coralline limestone containing Lower Niagara fossils is reported by Dr. Ami.

Foot-prints of *Hylopus* and *Sauropus*, and other evidences of Carboniferous, have been reported from the fossiliferous strata along the north shore of the Basin of Minas.

"The bone-beds of McAra Brook, holding crustacean and fish remains, were again examined and additional examples were obtained of a *Pteraspis*, which appears to be new (the genus having been identified by Dr. A. S. Woodward), and fragments of cephalaspidian and acanthodian species, besides indications of

Pterygotus. The occurrence of *Pteraspis* and *Pterygotus* indicate that the beds at McCara Brook, above and below the post-road, are referable to the summit of the Silurian system or the lowermost portion of the Devonian."

Mr. Lambe reports the following Cretaceous fossils from Red Deer River district of Alberta, viz.:

"Considering first the fossils from the Belly River formation, the following provisional enumeration may be made of them:—

1. Chelonia:

Fragments of the dorsal and ventral shield of *Plastomenus coalescens*, Cope.

2. Crocodilia:

Parts of the rami of mandibles of a species of *Bottosaurus*, Agassiz.

3. Dinosauria:

a. Numerous maxillæ and rami of mandibles and some of the principal bones of *Trachodon mirabilis*, Leidy.

b. A maxilla with teeth, a separate tooth and a right ramus of a species of *Triceratops*, Marsh.

c. Separate teeth and terminal phalanges of *Loelaps incrassatus*, Cope.

d. The upper part of the cranium of a species of *Nodosaurus*, Marsh."

W.

2. *The Hereford Earthquake of December 17, 1896*; by CHARLES DAVISON, Sc.D., F.G.S., 303 pp. 8vo. Birmingham, 1899 (Cornish Brothers).—The careful investigation of the phenomena connected with an important earthquake is a laborious undertaking, but one which is of great value in its bearing upon our knowledge of earthquakes in general. In the case of the Hereford earthquake of Dec. 17, 1896, discussed in the present volume, Dr. Davison has shown unwearied energy in bringing the data together and much judgment and skill in drawing conclusions from them.

Of the several regions in Great Britain in which notable earthquakes have taken place, that of the occurrence here described, in the southeast of Herefordshire, is especially favorably situated for observation both geographically and as regards distribution of population. Here occurred also the earthquake of October 6, 1863, investigated by Mr. E. J. Lowe; while another, less violent, occurred in October 30, 1868. In 1896, however, the shocks were more numerous and severe, resulting in a very considerable amount of damage to buildings in the region of greatest intensity about Hereford. The effect was distinctly felt even at extreme points in the north and south of England and in Ireland.

The record of observations, contained in Part I (pp. 10–201) of the present volume, includes some 2902 separate accounts from 1943 places. The discussion of these data has made it possible to locate with accuracy the epicentral region with the isoseismal lines; also the isacoustic lines, or lines of equal sound intensity; the direction of the shocks at various points with the coseismal

lines. From the last the mean surface-velocity deduced between the first and third coseismals is 2955 feet per second.

In regard to the origin of the earthquake the conclusion is reached that it was due to a slip along a fault many miles in length having a general northwest and southeast direction and passing very near to Hereford. Further that there were two foci, one to the northwest near Hereford some eight miles in length, and a second, southeast and near Ross, about six miles in length. Between these there was an undisturbed portion of the fault about two miles in length. The fault-slip at the Hereford focus took place a few seconds before that at the Ross focus, hence the distinctly noted double series of vibrations. The position of the fault-line is located within the area of the Old Red Sandstone, but its exact geological relations have not been established, though it is plausibly connected with a well-recognized anticlinal in the neighborhood, bounded on three sides by faults, one of which has nearly the direction of the fault-line above mentioned.

3. *First Appendix to the Sixth Edition of Dana's System of Mineralogy*, by EDWARD S. DANA; pp. x and 75. New York, 1899 (John Wiley & Sons).—The sixth edition of Dana's System of Mineralogy was issued in the early part of 1892. In the seven years that have passed, the additions to mineralogical literature have been numerous and important; a summary of these is given in the Appendix now published, which thus completes the System to 1899. The prefatory note states as follows: "This Appendix contains, first of all, full descriptions of the species announced as new since the publication of the System. There are no fewer than one hundred and seventy names here included, and their place in the general scheme of classification adopted in the System is shown in the classified list given in the Introduction. In addition to the description of new minerals this Appendix is intended to contain also references to all important papers on mineral species published during the period named; with each reference is given a concise statement of its character, and so far as possible a summary of its contents. Since, however, the additions to mineralogical literature have been very numerous, it has been necessary, in order to keep this work within reasonable compass, to adhere rigidly to a system of extreme brevity of expression and conciseness of arrangement. All minerals named are, for convenience, placed in alphabetical order. . . . The Bibliography includes the full titles of prominent volumes published since 1891."

4. *Minerals of Mexico*.—Boletín del Instituto Geológico de Mexico, num. II, pp. 157, 4to. Mexico, 1898.—The latest number of the Bulletin published by the Geological Institute of Mexico contains a full and valuable catalogue of the mineral species found in the country, prepared by Prof. JOSÉ G. AGUILERA. In it the minerals are arranged according to the classification in Dana's System, the individual localities being given fully in connection with each species.

5. *Clays and Clay Industries of Pennsylvania.* (1) *Clays of Western Pennsylvania in Part:* by THOMAS C. HOPKINS.—This volume is issued as an appendix to the Annual Report of the Pennsylvania State College, for 1897. In it Professor Hopkins has given an interesting and instructive account of the various clays obtained in Western Pennsylvania, and further a description of the industries connected with their use. Numerous excellent illustrations accompany both parts of the subject.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Eruption of Mauna Loa.*—Honolulu papers of July 8 to 10 contain accounts of the beginning of an eruption of the volcano of Mauna Loa, on Hawaii. Early in the morning of July 4th, one observer says, "an immense column of smoke and steam was seen rising from the crater of Mokuaweoweo. It was pierced through with the light from the fires beneath, until it glowed and shone like a column of fiery light, resplendent beyond description, and reflecting its burning glow over the whole heavens. The column seemed to be at least five miles in diameter, and rose to a tremendous height. On Tuesday, the column of fire had disappeared. In place of it was the equally impressive glow of the lava as it broke from the lower side of the crater several thousand feet lower down than the column of light had been, and was thrown upward to a wonderful height by the forces which were in action. On either side of the stream, whose surface of fiery red could be seen like a line of glowing molten metal, were two cones which had formed since the eruption began. It was from these that the lava was being ejected. It was thrown up in fiery cascades high in the air. These cascades, in falling, built up the cones, and the molten lava running off from these formed the stream flowing off toward Hilo. It would be hard to say how high these cones were, perhaps somewhere between 500 and 1000 feet high, and half a mile in diameter, and five miles apart." A later account mentions three lava streams, one in the direction of Hilo, another off through Kau to the southeast, and a third toward the crater of Kilauea.

Attention may be called in this connection to a paper by Mr. C. J. Lyons of Honolulu on "Sun Spots and Hawaiian Volcanoes" published in the April number of the *Monthly Weather Review*. The author gives a table of the years of minimum sun spots for the past century, with the dates of prominent volcanic eruptions of Kilauea or Mauna Loa, showing a striking correspondence between the times of the two phenomena. As pointed out by the editor of the *Review*, however, a more thorough investigation is needed to prove that the coincidence noted is due to a real causal connection.

The table referred to is as follows:

Years of minimum sun spots.	Years of most important lava flows or eruptions.
(?) -----	1790 (Kilauea Keoua eruption).
1799 -----	1801 Hualalai.
1810 -----	(?) -----
1823 -----	1823 Mauna Loa.
1833 -----	1832 Mauna Loa and Kilauea.
1843 -----	1840 Kilauea.
	1843 Mauna, Loa.
	1852 } -----
1856 -----	1855 } Mean 1856, Mauna Loa.
	1859 } -----
1867 -----	1868 Mauna Loa.
1878 -----	1880-81 Mauna Loa.
1889 -----	1887 Mauna Loa, south slope.
1900 (Probable) -----	-----

2. *British Association*.—The coming meeting of the British Association for the Advancement of Science is to be held at Dover during the week beginning Sept. 13th. The occasion is expected to be a notable one and of international character, since the French Association meets at the same time at Boulogne and visits are planned for the two scientific bodies, on September 16 to Dover and on Sept. 21 to Boulogne.

3. *American Association*.—The summer meeting of the American Association for the Advancement of Science was held at Columbus, Ohio, from August 21-26. An account of the meeting must be postponed to the following number.

4. *Sprachregeln für die Bildung und Betonung Zoologischer und Botanischer Namen*; von PAUL KRETSCHMER. 8vo, 32 pp. Berlin: 1899 (R. Friedländer & Sohn).—This pamphlet gives very full and carefully prepared grammatical rules for the formation and accentuation of zoological and botanical names and should be consulted by every naturalist interested in systematic nomenclature. S. I. S.

5. *Anleitung zur Darstellung Chemischer Präparate*, von Prof. Dr. H. ERDMANN. 2 Auflage; pp. 92. Frankfurt, 1899 (H. Bechold).—The first edition of Prof. Erdmann's little book on Inorganic Preparations appeared nine years ago, and has been very favorably received. This new edition, containing a few additional preparations, with numerous corrections and improvements, will, therefore, be welcomed by those who are interested in teaching experimental chemistry. H. L. W.

OBITUARY.

Sir WILLIAM HENRY FLOWER, K.C.B., F.R.S., the distinguished Zoologist, late Director of the Natural History Department of the British Museum, died on July 1 in his sixty-eighth year. His contributions to zoology, anatomy and anthropology were numerous and important, and in his capacity of museum curator he performed a work of great and lasting value, the influence of which has been widely felt in other institutions at home and abroad.

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FOURTH SERIES.

VOL. VIII—[WHOLE NUMBER, CLVIII.]

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PLATE V.

NEW HAVEN, CONNECTICUT.

1899.

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AUSTRALIA.—The following are worthy of separate description, though other notable species are only named in this limited space.

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T H E

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVI.—*Explosive effect of Electrical Discharges*; by JOHN TROWBRIDGE, T. C. MCKAY and J. C. HOWE. With Plate V.

SINCE the time of Franklin the subject of the explosive effect of electrical discharges has been studied by numerous investigators, and an extended bibliography of their work is contained in Wiedemann's "Galvanismus und Electromagnetismus."

The resources of the Jefferson Physical Laboratory permitting the study of this phenomenon over greater range than has hitherto been possible, we have undertaken the work in the hope of further elucidating the subject. The laboratory possesses two high tension transformers or Planté rheostatic machines—one giving discharges of 125 centimeters in length, and one yielding sparks 180 to 200 centimeters in length. These transformers are connected to a battery of ten thousand cells, and can yield voltages from twenty thousand to three million. Various methods of measurement were tried. On account of the great tension all galvanometric and electrometric means had to be abandoned; and what is known as the electric thermometer was finally adopted. This consists, as is well known, of a hermetically closed glass tube, provided with a manometer gauge. The electrical discharge passes through the tube by means of a fine wire, or by a spark gap. The term electrical thermometer is a misleading one; for as we shall show, the quick movement of the manometer gauge is not due to heat.

At first we passed the discharges through very fine wire. The gauge, which consisted of a bent glass tube containing an

index of bichromate of potash, rose suddenly at each discharge and returned approximately to the zero point. When, however, the wire had been heated by repeated discharges, the index showed a slow rise in temperature. Even when the terminals in the glass tube were connected by a fine wire, a very strong electrostatic field was created in the tube. This is shown in an interesting manner by fig. 1 (Plate V). This photograph was obtained by stretching a fine wire over a photographic plate and sending a single discharge through the wire, there being no spark gap in the circuit. The fine wire vibrated during the discharge; and when the negative thus obtained was closely examined, subsidiary vibrations were shown by many black lines approximately parallel to each other. These lines were apparently caused by the heat of the discharge melting the gelatine where the wire came in close contact with the film. The electrostatic field about the wire is exhibited by a fern-like discharge at right angles to the wire.

We were soon convinced that heat played a subordinate part in the phenomenon shown by the quick rise of the manometer index. This rise was apparently dependent upon the electrostatic conditions rather than upon thermodynamic or magnetic phenomena. We, therefore, abandoned the fine wire connection and employed a spark gap having a range from zero to eighty centimeters. It was possible to still further extend this range to two hundred centimeters; but it was found that the range from zero to eighty centimeters exhibited the main features of the phenomenon. The following table gives the results obtained with discharges produced by three million volts, 10,000 Planté cells, 150 condensers, charged in multiple and discharged in series; pointed brass terminals in large glass cylinder; gauge consisting of a bent glass tube with a potassium bichromate index; R_1 and R_2 , readings of gauge before and after discharge; D , difference of these readings in centimeters; F , distance between terminals.

It will be seen from the curve A, fig. 2, that the explosive effect increases closely proportional to the length of the spark until the length of fifty centimeters is reached. It then begins to diminish. This decrease occurs with the increase of electrostatic effect in the field surrounding the spark gap,—or in other words, with the divergence or spreading of the electric lines of force. The electrostatic effect in this field, when a difference of potential of three million volts is generated, is very great. Sparks can be drawn from neighboring objects. Shocks are felt when the observers touch each other; and photographic plates, shielded from light in plate holders, held at distances of five or six feet from the terminals, exhibited, on development, brush discharges, or Lichtenberg figures.

F	R ₁	R ₂	D	Average.	F	R ₁	R ₂	D	Average.
10	4.4	4.9	.5		38	4.7	6.7	2.0	
"	4.6	5.0	.4	0.45	"	5.1	7.3	2.2	
					"	5.5	7.7	2.2	2.1
17	4.5	5.5	1.0		46	4.8	7.2	2.4	
"	4.7	5.2	.5		"	5.3	7.7	2.4	
"	4.8	5.5	.7		"	5.5	7.9	2.4	
"	5.0	6.2	1.2	0.9					2.4
24	4.7	6.0	1.3		53	5.1	7.3	2.2	
"	5.	6.2	1.2		"	5.4	7.7	2.3	
"	5.3	6.5	1.2	1.2	"	5.6	7.3	2.7	
					"	5.2	7.1	1.9	
					"	5.4	7.5	2.1	2.2
31	4.8	6.7	1.9		60	4.7	6.2	1.5	
"	4.8	6.6	1.8		"	5.7	7.3	1.6	
"	5.4	7.2	1.8	1.8	"	5.4	7.6	2.2	
					"	5.5	8.1	2.6	
					"	5.2	7.1	1.9	
					"	5.2	7.6	2.4	
					"	5.2	7.5	2.3	2.1
					67	4.8	7.0	2.2	
					"	5.1	7.1	2.0	
					"	5.3	7.3	2.0	
					"	5.5	6.7	1.2	
					"	5.2	7.1	1.9	
					"	5.4	7.3	1.9	
					"	5.5	7.6	2.1	1.9
					74	4.8	6.4	1.6	
					"	5.1	6.6	1.5	
					"	5.3	6.9	1.5	
					"	5.3	7.3	2.0	
					"	5.4	7.2	1.8	
					"	5.5	7.3	1.8	1.7
					80	4.8	5.2	.4	
					"	4.5	6.3	1.8	
					"	5.0	5.9	.9	
					"	5.1	5.4	.3	1.1

The measurements were next repeated, while, at the same time, spark discharges were measured in a transformer circuit, the primary of which was in the circuit of the high tension transformer or Planté machine. In the following table column A contains the length of spark in the primary circuit, or circuit of the Planté machine; column B, the length of spark in the secondary coil circuit.

A	B	A	B
0	2.5	14	3.0
1	2.7	16	2.8
2	3.0	20	2.6
3	3.0	30	1.7
4	3.0	40	1.8
5	3.0	50	1.6
6	3.2	60	1.3
7	3.3	70	1.2
		80	1.2
			1.

When these results are plotted the lower curve, B, fig. 2, shows that the spark-length in the secondary circuit increases while the primary spark-length is increased up to seven centimeters. When, however, the primary spark-length is increased to fourteen centimeters, the length of the secondary spark begins to diminish. Thus the maximum of the curve B is a little in advance of the minimum of the curve representing the explosive action. Since the magnetic flux through the little transformer is proportional to the strength of the current in the primary circuit, it is seen that the explosive effect is not due to the heat produced by the current. Previous experiments by one of us had shown* that the apparent resistance of the primary spark did not increase with the length of the spark. The diminution in magnetic flux is due not to increase of resistance in the primary circuit but to a shunting through the air of the current in this circuit. Fig. 1 shows how great this shunting action can be even with closed circuits under the action of high electromotive force. The explosive effect, therefore, we are inclined to attribute primarily to an electrostatic action. When the primary spark gap is small, a silent discharge lowers the difference of potential between the spark terminals. As the distance between these terminals increases, the silent discharge diminishes, and the difference of potential increases until a point is reached at which strong inductive efforts take place between all surrounding objects.

The energy of the electrostatic field thus manifests itself by what we may, perhaps, term an ionization and electrical attraction and repulsion of the particles of the air. This electrostatic action does not extend to the great distances reached by the electromagnetic effect of the field. While the latter can be detected many miles, the electrostatic effect is confined to a few feet. Thus a spark of six or seven feet in length (180 to 210 centimeters) is vastly inferior to one of two or three inches (5 to 7.5 centimeters) for the purposes of wireless telegraphy. In experiments with electric waves by means of coherers we

* Proc. American Academy of Arts and Sciences, vol. xxxiii, No. 24.

found that the electrostatic effect was very disturbing up to a distance of twenty feet from the spark terminals, when these terminals were six feet apart. The disturbance diminished as the terminals were brought nearer together. The minimum of the curve representing this disturbance coincided with the minimum of the curve representing the explosive effect. On the other hand, the action of the magnetic waves on the coherer becomes regular beyond a distance of about twenty feet.

The electrostatic effect is evidently some function of the electrical density on the terminals of the spark gap and on the coatings of the condenser. The following experiments illustrate this dependence of the sparking distance upon this density. A chronograph cylinder was provided with two pointers S and S', fig. 3, one of which was connected to one coating of a condenser C, while the other coating of the condenser was joined to the metal cylinder of the chronograph. The coatings of the condenser were charged through an adjustable very large liquid resistance by means of ten thousand cells B. The other pointer was connected with one terminal of a small Ruhmkorff coil I, while the other terminal wire of the coil was led to the cylinder of the chronograph. The primary of the Ruhmkorff coil was interrupted by a second pendulum which broke the circuit at S. The pointers were placed on a carriage. When this was released, the pointers drew lines on blackened paper, fig. 4, placed upon the chronograph cylinder; and the number of the discharges of the condenser in one second could be estimated. With small resistance between the battery and the plates of the condenser the number of discharges in a second was very great. This number decreased as the resistance increased, and was approximately inversely proportional to this resistance. The condensers were of glass, of rubber, and an air condenser was also employed. In every case the number of discharges was inversely proportional to the resistance between one plate of the condenser and the battery.

Since the frequency of the discharge of the condenser depended upon the resistance between one plate of the condenser and the battery, it was evident that the energy of the battery was employed to charge the condenser to a sufficient surface density to enable a spark to be formed. A portion of this energy was wasted. This silent discharge can be regarded as a species of ionization. The condenser with its terminals forms a species of voltaic cell with a phenomenon of polarization. If the capacity of the condenser was increased, the effect was the same as that produced by increasing the resistance, as far as diminishing the number of discharges in a second. The energy of each discharge in this case was not

similarly diminished, since the entire strength of the battery served to charge the condensers.

In the phenomenon of the explosion produced by electrical discharges we are, therefore, dealing with electrostatic effects rather than with heat phenomena; and very high potentials bring to light in a marked way the phenomena of the electrostatic field. With differences of potential above one million volts ordinary air becomes a fairly good conductor. The electric force diminishes much more rapidly with the distance than the magnetic force (shown by Hertz). Phenomena of light are produced in the electrostatic field; and there are movements of molecules which may be embraced under the broad term ionization.

We are, therefore, led to the following conclusions:

1. The explosive effect of electrical discharges is due to an electrostatic effect rather than to a heat effect.

2. A strong analogy exists between the terminal conditions existing in electrical discharges and those of the electrodes of an ordinary voltaic cell. The electrical density on the terminals of a condenser is proportional to the strength of current which the charging battery is capable of producing.

3. The electrostatic field, diminishing much more rapidly with the distance than the electromagnetic field, doubtless has its energy consumed in molecular movements.

Jefferson Physical Laboratory,
Harvard University, U. S.

ART. XXVII.—*Experiments relative to the Constitution of Pectolite, Pyrophyllite, Calamine, and Analcite*; by F. W. CLARKE and GEORGE STEIGER.

IN a series of investigations by Clarke and Schneider which were carried out in the laboratory of the United States Geological Survey between 1889 and 1892,* a number of reactions were examined which shed some light upon the constitution of several natural silicates. The work then begun was unfortunately interrupted for several years; but it is now resumed, with the hope that it may be pushed considerably further.

Two of the reactions studied by Clarke and Schneider were of peculiar interest. First, in the case of talc, it was found that one-fourth of the silica could be liberated by ignition; and that the fraction thus set free was measurable by solution in aqueous sodium carbonate. This reaction suggests that other acid metasilicates may behave in a similar way, and that we perhaps have a means of discrimination between such salts and other compounds which simulate them. In other words, an acid metasilicate may be experimentally distinguished from a pseudo-metasilicate by the way in which it splits up when ignited. Evidence bearing upon this supposition will be found in the present paper.

The second of the reactions just referred to is that between dry ammonium chloride, at its temperature of dissociation, and various silicates.† This involves, in part at least, the action of dry gaseous hydrochloric acid upon the compounds which are studied; and different minerals are very differently attacked. Some are almost completely decomposed, others are affected but slightly; and here again there seems to be a method of diagnosis which deserves further attention. Both reactions suggest the main purpose of the investigation; which is, the fractional analysis of silicates by means of various reagents, in order to gain evidence bearing upon their chemical structure. The evidence at least is of value, whether the interpretation of it be right or wrong. Each fact helps to the ultimate solution of the central problem, the problem of constitution.

Pectolite.

The pectolite which was chosen for examination was the well-known radiated variety from Bergen Hill, N. J. The mineral was in long white needles, and apparently quite pure;

* This Journal, III, vol. xl, pp. 303, 405, 452; vol. xlii, p. 242; vol. xliii, p. 378.

† Bulletin No. 113, U. S. Geological Survey, p. 34.

but the analysis shows that it contained some carbonate as an impurity. Enough of the material was ground up to furnish a uniform sample for the entire series of experiments, and the work properly began with a complete analysis. The results obtained are as follows:

Analysis.		Fractional water.	
SiO ₂	53·34	Water at 105°	0·27
Al ₂ O ₃	·33	“ “ 180°	0·16
CaO	33·23	“ “ 300°	0·22
MnO	·45	“ “ redness ...	2·32
Na ₂ O	9·11		
Total H ₂ O ...	2·97		2·97
CO ₂	·67		
<hr/>			
100·10			

All of the water was given off at a barely visible red-heat; and the figures show that practically all of it is constitutional; a fact which perhaps hardly needed reverification. The analysis gives the accepted formula for pectolite,



Does this represent, as is commonly assumed, a true metasilicate? If it does, we should expect that ignition would split off silica proportional to the acid hydrogen, or one-sixth of the total amount. To answer this question several portions of the pectolite were sharply ignited, to complete dehydration, and then boiled each for fifteen minutes with a solution of sodium carbonate containing 250 grams to the liter. In the extract so obtained the silica was determined; and three experiments gave the following percentages:

8·96
8·67
8·42

Mean, 8·68

One-sixth of the total silica is 8·89 per cent; and the experiments, therefore, justify the original expectation. The belief that pectolite is a metasilicate is effectively confirmed.

Upon the unignited pectolite the sodium carbonate solution has a slow decomposing action, both silica and bases being withdrawn. In two experiments fifteen minutes of boiling extracted 2·07 and 2·55 per cent of silica, and by a treatment lasting four days 4·80 per cent was taken out. With water alone similar results were obtained; the action being so rapid, although relatively slight, that pectolite, moistened, gives an immediate and deep coloration with phenol phthalein. By

boiling the powdered pectolite with distilled water alone, 1.65 per cent of silica was brought into solution, and the ignited mineral, similarly treated for fifteen minutes, gave 1.78 per cent. The extraction in these cases is really an extraction of alkaline silicate; as the two following experiments prove. In A the unignited pectolite was boiled for fourteen hours with distilled water; and in B the mineral after ignition was subjected to like treatment for four hours. The dissolved matter in each case was determined, with the subjoined results:

Extracted.	A.	B.
SiO ₂	2.98	3.03
CaO .....	.30	.10
Na ₂ O .....	.81	1.50
	<hr/> 4.09	<hr/> 4.63

In A, no simple ratio appears; but in B the extracted silicate approximates very nearly to the salt Na₂Si₂O₅. In each instance the ratios vary widely from those of the original mineral, showing that actual decomposition and not a solution of the pectolite as such has occurred.

In the experiments upon pectolite the heating with dry ammonium chloride was omitted, for the data are already given in the original paper by Schneider and Clarke. In their experiments the mineral was thrice heated with ten times its weight of the reagent to above 350°, and then leached out with water. In the solution 20.50 per cent of lime and 6.95 of soda were found, with part of the manganese; showing that a very considerable decomposition had taken place. Possibly, by repeated treatments with ammonium chloride a complete decomposition might be effected; but this question is one upon which it seemed unnecessary to spend further time.

Pyrophyllite.

The empirical formula for pyrophyllite, AlHSi₂O₆, is apparently that of an acid metasilicate, and the mineral is therefore peculiarly available for fractional analysis. The compact variety from Deep River, N. C., was taken for examination, and a uniform sample was prepared. Analysis gave the following results:

SiO ₂	64.73
TiO ₂ .....	.73
Al ₂ O ₃	29.16
Fe ₂ O ₃ .....	.49
MgO	trace
Ignition	5.35
	<hr/> 100.46

If now, pyrophyllite is an acid metasilicate it should break up on ignition in accordance with the equation



That is, one-fourth of the silica, or 16.18 per cent, should be liberated. The mineral itself is very slightly attacked by boiling with the sodium carbonate solution, and in an experiment of this kind only 0.72 per cent of silica was dissolved. Upon ignition under varying circumstances the following data were obtained:

Ignited ten minutes over a Bunsen burner, and then extracted with sodium carbonate solution, 1.51 per cent of SiO_2 dissolved.

Ignited fifteen minutes over a Bunsen burner, 1.89 per cent became soluble.

Ignited ten minutes over a Bunsen burner and then fifteen minutes over the blast, 2.84 per cent of silica was liberated.

These results are of a different order from those given by pectolite and talc, and raise the question whether pyrophyllite, despite its ratios, is a metasilicate at all. So far as the evidence goes, it may with propriety be regarded as a basic salt of the acid $\text{H}_2\text{Si}_2\text{O}_5$, and its formula then becomes



This formula is at least as probable as the metasilicate expression, which latter rests upon assumption alone. Still other formulæ, but of greater complexity, are possible; but until we know more of the genesis and chemical relationships of pyrophyllite, speculation concerning them would be unprofitable.

By heating with dry ammonium chloride, pyrophyllite is very slightly attacked. In two experiments it lost in weight 6.17 and 6.30 per cent respectively. The excess of loss over water is due, as we have proved, to the volatilization of a little ferric and aluminic chloride. The residue of the mineral after this treatment contained no chlorine, so that no chlorhydrin-like body had been formed. The formation of such a compound, the replacement of hydroxyl by chlorine, would, if it could be effected, be a valuable datum towards determining the actual constitution of the species.

Calamine.

The simplest constitutional formula for calamine, the one which is generally accepted, represents it as a basic metasilicate, $\text{SiO}_3 = (\text{ZnOH})_2$. In this the hydrogen is all combined in one way, and so, too, is the zinc. In all other possible formulæ,

simple or complex, the hydrogen as well as the zinc must be represented as present in at least two modes of combination; a condition of which, if it exists, some evidence should be attainable. Our experiments upon calamine have had this point in view; and we have sought to ascertain whether water or zinc could be split off in separately recognizable fractions. Our results, in the main, have been negative, and tend towards the support of the usual formula; but the data are not conclusive, although they seem to be worthy of record.

The beautiful, white calamine from Franklin, N. J., was selected for study, and gave the subjoined composition:

Analysis.		Fractional water.	
SiO ₂	24.15	At 100° .....	.27
Al ₂ O ₃ , Fe ₂ O ₃ .....	.19	" 180° .....	.22
ZnO	67.55	" 250° .....	.75
CaO .....	.12	" 300° .....	.88
H ₂ O	7.95	Incipient red heat.....	4.46
		Full red heat.....	1.37
	<hr/> 99.96		<hr/> 7.95

Here no clear and definite fractionation of the water is recognizable, at least of such a character as to suggest any other than the ordinary formula for calamine.

Upon boiling powdered calamine with water, practically nothing went into solution, but by boiling with the solution of sodium carbonate, 0.25 per cent of silica was dissolved. After ignition at a red heat, only 0.14 per cent of silica became soluble in sodium carbonate, and after blasting, only 0.24. In these experiments a very little zinc was dissolved also; but there was no evidence that any breaking up of the mineral into distinguishable fractions had occurred. In a hot ten per cent solution of caustic soda both the fresh and the ignited calamine dissolve almost completely; but boiling with aqueous ammonia seems to leave the mineral practically unattacked. All experiments aiming to extract a definite fraction of zinc while leaving a similar fraction behind, resulted negatively.

By heating with dry ammonium chloride, calamine is vigorously attacked, and gains in weight by absorption of chlorine. In two experiments the mineral was intimately mixed with three times its weight of powdered salammoniac, and heated in an air-bath for several hours to a temperature somewhat over 400°. A large part of the residue was soluble in water, and the percentage of this portion, together with the percentage increase in weight, is given below.

	I.	II.
Gain in weight	27.60	25.78
Soluble in water	53.23	67.13

A conversion of calamine into the chlorhydrin, $\text{SiO}_2(\text{ZnCl})$, would involve a gain in weight of 15.34 per cent. Complete conversion into $2\text{ZnCl}_2 + \text{SiO}_2$ implies an increase of 38.14 per cent. The figures given lie between these two; and are indefinite also for the reason that there was volatilization of zinc chloride.

In two more experiments the calamine, mingled with three times and four times its weight of ammonium chloride respectively, was heated for an hour and a half to bright redness in a combustion tube. The zinc chloride which was formed, volatilized, and was collected by suitable means for determination. It corresponded to 59.6 and 59.0 per cent of the original mineral, calculated as zinc oxide; which indicates a nearly complete decomposition of the calamine into $2\text{ZnCl}_2 + \text{SiO}_2$. The residue was mainly silica, with a small part of the zinc, about half of the silica being soluble in sodium carbonate solution. Here again no definite fractionation of the mineral could be observed.

Finally the action of dry hydrogen sulphide upon calamine was investigated. The mineral was heated to redness in a current of the gas, and gained perceptibly in weight. The percentage data, reckoned on the original calamine, were as follows, in two experiments:

	I.	II.
Gain in weight	6.00	6.43
SiO_2 soluble in Na_2CO_3	16.45	20.95
Sulphur in residue	----	24.12

Complete conversion of calamine into $2\text{ZnS} + \text{SiO}_2$ implies a gain in weight of 5.80 per cent; and it is therefore evident from the figures of the second experiment that the limit of change was approached very nearly. The 24.12 of sulphur taken up is quite close to the 26.53 per cent which is required by theory. About eight-ninths of the calamine had undergone complete transformation. Again, no definite fractionation was detected.

The hydrogen sulphide reaction was examined still further with reference to the temperature at which it becomes effective. Even in the cold, calamine is slightly attacked by the gas, but its action is unimportant until the temperature of 400° is approximated. Then it becomes vigorous and the reaction goes on rapidly. A few experiments with willemite showed that it also was attacked by hydrogen sulphide, but less vigorously than calamine.

Analcite.

Analcite, from many points of view, is a species of peculiar interest, and of late years it has received a great deal of attention. Its formula may be written in various ways, especially as regards the interpretation of its one molecule of water; but evidence too often has yielded before pre-conceived opinion. Additional evidence is now available, partly from the experiments of Friedel, and partly from the data obtained during the present investigation.

The analcite examined by us was in well-developed crystals from Wasson's Bluff in Nova Scotia. A uniform sample was prepared, as usual, and the analysis, given below, is contrasted with the theoretical composition required by the accepted empirical formula $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$.

	Found.	Calculated.	Fractions of water.
SiO ₂ -----	57.06	54.55	At 100° ----- .58
Al ₂ O ₃ -----	21.48	23.18	“ 180° ----- 1.16
Fe ₂ O ₃ -----	.13		“ 260° ----- 3.64
CaO -----	.16		“ 300° ----- 1.57
Na ₂ O -----	12.20	14.09	Low redness... 1.90
H ₂ O at 100° -----	.58		Full redness... .11
“ over 100° -----	8.38	8.18	Blast ----- none
	<hr/> 99.99	<hr/> 100.00	<hr/> 8.96

The fractional water determinations were made by heating in an air-bath to constant weight at each temperature up to 300° , and finally over the direct flame. The first fraction, at 100° , is evidently hygroscopic or extraneous water, which can be disregarded. The remainder of the water, 8.38 per cent, belongs to the species. The significance of the analytical figures will be considered later.

Upon boiling the powdered analcite with sodium carbonate solution, 250 grams to the liter as in all the preceding experiments, 0.73 per cent of silica was extracted. After ignition the mineral in two determinations yielded 1.46 and 1.38 per cent respectively. The splitting off of silica is therefore very slight; and one of the formulæ proposed by Doelter,* $\text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 + 2\text{H}_2\text{SiO}_3$ may be set aside as improbable. Metasilicic acid or an acid metasilicate can hardly be present in analcite; although the possibility of a neutral metasilicate, as indicated by the empirical formula, is not excluded. By Doelter's formula one-half of the silica ought to be removable.

Upon heating analcite with dry ammonium chloride, results of a remarkable character were obtained. Sodium chloride

* Neues Jahrb., 1890, i, 133.

was formed, which could be leached out by water and measured; while ammonia, free from chlorine, was retained by the residue to a notable and surprisingly stable degree. The experiments in detail were as follows:

- A. Analcite, mixed with four times its weight of ammonium chloride, was heated for four hours to 350° . There was a gain in weight of 2.18 per cent, and 6.10 per cent of soda, or one-half of the total amount, was converted into NaCl, which was leached out by water, examined as to its purity, and weighed. In the residue 1.20 per cent of silica was extractable by sodium carbonate, showing that no more splitting off had occurred than was previously observed. The gain in weight, as will be seen from subsequent experiments, is due to the fact that all of the NH_4Cl had not been driven off; or else that more water was retained.
- B. Analcite was ground up with four times its weight of NH_4Cl , heated for several hours, reground with another four-fold portion of chloride, and heated to 350° for 21 hours. Gain in weight, 0.08 per cent. 5.57 per cent of soda was extracted as chloride.
- C. Analcite heated to 350° for 8 hours, with four times its weight of NH_4Cl . Loss of weight, 0.10 per cent.
- D. Six grams of mineral and 28 of chloride, mixed by thorough grinding, was heated to 350° for 14 hours; then was reground with 28 grams of fresh NH_4Cl and heated for 35 hours. Loss of weight, 0.13 per cent. 5.07 per cent of soda was extracted as chloride; plus 0.14 of ammonium chloride unexpelled. 2.03 per cent of silica was rendered soluble in sodium carbonate.

So far, three facts are noticeable. First, the weight of the mineral after treatment is almost exactly the same as before; showing that gains and losses have balanced each other. Secondly, little silica has been split off. Thirdly, approximately, but not rigorously, one-half of the soda has been converted into NaCl. In A, it was exactly half; in the other experiments, a little less than half. Furthermore, in the sodium chloride dissolved out there is only a very little ammonium chloride, amounting at most to 0.14 per cent, calculated upon the weight of the original mineral.

In the residue of the analcite after extraction of sodium chloride, abundant ammonia can be detected, with either no chlorine or at most a doubtful trace. If, however, the unleached mineral, still retaining its sodium chloride, be heated strongly, say from 400° up to redness, NH_4Cl is regenerated and given off. Its absence, as such, both from the leach and the residue was repeatedly proved. The ammonia and water retained by the analcite after heating to 350° with ammonium

chloride were several times determined; and the following percentages, still reckoned on the original mineral, were found:

	NH ₃ .	H ₂ O.
In B	2·03	2·25
" C	2·19	2·00
" D	2·36	1·89
" "	2·35	----
" "	2·06	----
Mean	2·20	2·04

Correcting the ammonia for the 0·14 of NH₄Cl found in D, the mean value becomes 2·15. This permanent ammonia is not given off upon warming the material with caustic soda solution; and is therefore not present as a salt. The determinations of it were made by three distinct methods, and there is no possible doubt as to its presence and character.

The composition of the analcite after the treatment with ammonium chloride may now be considered, with the subjoined combination of the data. The NaCl in A, 11·50 per cent, was in material which had gained 2·18 per cent, and is subject to a correction which reduces the figure to 11·26. In B, C, and D the corresponding correction is so small that it may be neglected. The last column gives the composition of the leached residue, recalculated to 100 per cent, after deduction of NaCl and the soluble silica. The letters refer back to the several experiments, and the little iron is included with the alumina.

	A.	B.	C.	D.	Average. Residue.	
Sol SiO ₂ ..	1·20	----	----	2·03	1·61	----
Insol. SiO ₂				54·96	54·96	62·59
Al ₂ O ₃				21·37	21·37	24·34
CaO				·16	·16	·18
NaCl	11·26	10·50	----	9·57	10·44	----
Na ₂ O				7·12	7·12	8·11
NH ₃	----	2·03	2·19	2·21	2·15	2·46
H ₂ O	----	2·25	2·00	1·89	2·04	2·32
				99·31	99·85	100·00

The analcite residue, like the original mineral, is completely decomposable by aqueous hydrochloric acid. It may be a mixture; but it seems more probable that it is a definite compound; for it approximates in composition to the formula



This represents a quadrupled analcite formula, in which half of the sodium is replaced by hydrogen, and with NH_3 in place of $4\text{H}_2\text{O}$. The analytical comparison is as follows:

	Found.	Calculated.
SiO_2	62.59	61.46
Al_2O_3	24.34	26.12
CaO} .....	.18	----
Na_2O	8.11	7.94
H_2O	2.32	2.30
NH_3	2.46	2.18
	<hr/> 100.00	<hr/> 100.00

The agreement is not close, but it is close enough to be suggestive, and to indicate the character of the reaction which has taken place. It needs, however, verification by additional experiments upon other preparations, and upon analcite from other sources. In this connection it may be well to reiterate that the substance was prepared by very long heating at 350° , and is therefore stable at that temperature.

An interesting feature of these experiments is their harmony with the researches of G. Friedel,* who has shown that the water of zeolites may be replaced by ammonia and other substances, without change of the crystalline structure. In the case of analcite, ammonia was taken up to the extent of 2.04 per cent; or almost exactly the amount found in our analcite residue. The great difference between Friedel's method of experimentation and ours, renders the agreement all the more striking; and sustains our belief that the mineral and the residue are compounds of the same general order. We hope to continue our experiments and to extend our investigation to other zeolites.

If, now, analcite and its derivative, our analcite residue, are analogous compounds, the relation between them is expressed by these formulæ:



That is, the minimum molecular weight assignable to analcite is represented by four times its empirical formula. Other interpretations of the evidence are possible, but this appears to be the simplest. The water of analcite, as Friedel has shown, must be regarded as water only, not as hydroxyl; for it can be expelled by heat without destruction of the crystalline nucleus, the anhydrous salt, and is taken up again from moist air.

* Bull. Soc. Min., xix, 94, 1896.

But whatever its mode of union may be, the amount of water corresponds to the simple molecular ratio which is indicated in the formula of the species. One molecule of analcite holds a certain definite number of water molecules; and Friedel's observations are not incompatible with the idea that these are retained with varying degrees of tenacity. This idea is suggested by the various series of fractionation experiments which have been made from time to time, by independent workers, even though the data are not by any means concordant. Thus Lepierre* found that half the water of analcite was driven off at or below 300°, the other half above 440°. In our own experiments three-fourths were expelled at 300°, the remaining fourth being held up to a much higher, but undetermined temperature. In both series the water fractions are representable by fourths; but Friedel's experiments† indicate a continuity of loss in weight of quite a dissimilar order. Friedel holds that all of the water fractionations heretofore made upon analcite are fallacious, and that no definite fractions can be identified, a conclusion strongly supported by his own data, even though the proof is not absolutely positive. The most that can be said is, that the weight of evidence, so far, is in favor of Friedel's contention, but that additional investigation is necessary in order to reconcile all discrepancies. The full significance of the water in analcite remains unknown.

In order to discuss the constitution of analcite, let us recur to the analysis of the mineral itself. It is at once evident from the comparison made on a preceding page that our sample of the mineral varies notably in composition from the requirements of theory. The silica is two and one-half per cent too high, while alumina and soda are correspondingly low. No probable impurity and no presumable errors of manipulation can amount for so great a divergence. If we consult other analyses, as we find them tabulated in manuals like those of Dana and of Hintze, we shall find other cases resembling this, and also examples of variation in the opposite direction, with silica low and an apparent excess of bases. Most analcite gives quite sharply the metasilicate ratios required by the accepted formula; but the variations from it are large enough, common enough and regular enough to command attention. The analyses are not all covered by the recognized theory; and the apparent irregularities are not fortuitous, but are systematic in character.

One explanation of the seeming anomalies is simple and clear. If analcite, instead of being a metasilicate, is really a

* Bull. Soc. Chim. (3), xv, 561, 1896.

† Bull. Soc. Min., xix, 363, 1896.

mixture of ortho- and trisilicate, then all of the analyses become intelligible. In most cases the two salts are commingled in the normal ratio of one to one; but in our analcite the trisilicate predominates, while in some other samples the ortho-salt is in excess. All reduce alike to the simple expression



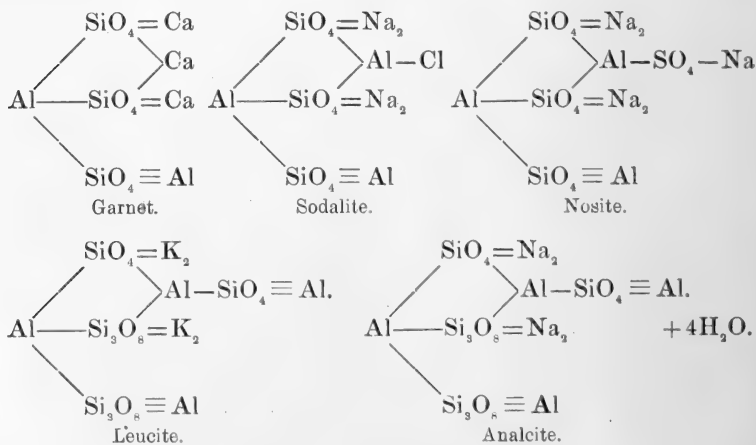
in which X represents $n\text{SiO}_4 + m\text{Si}_3\text{O}_8$; a formula which agrees with evidence from various other sources.

For example, analcite may be derived in nature either from albite, $\text{AlNaSi}_3\text{O}_8$, or nephelite, AlNaSiO_4 , and on the other hand alterations of it into feldspars have been observed. Its closest analogue, leucite, has yielded pseudomorphs of orthoclase and clæolite; while leucite and analcite are mutually convertible each into the other. The evidence of this character, the evidence of relationship between analcite and other species, is varied and abundant; and the simplest conclusion to be drawn from it is that which has been given. Every alteration, every derivation, every variation in the composition of analcite, points to the same belief. The consistency of the data cannot well be denied.

In the case of a normal analcite, that is, one which conforms to the usual empirical formula, the expression which best represents these relations is



and this accords with the minimum molecular weight as determined by the study of our ammoniated residue. Structurally, this is comparable with the formulæ of garnet, zunyite, sodalite, nosite and leucite; all of which are also isometric in crystallization. The more important of the symbols are as follows:



That is, analcite and leucite become members of the garnet-sodalite group of minerals, and their relations to nephelite, albite, prehnite, natrolite, etc., natural and artificial, are perfectly clear. In analcite there may be admixtures of strictly analogous ortho- or trisilicate molecules; but these remain to be separately discovered.

Now these formulæ are not ultimate verities to be blindly accepted. They are simply expressions which represent composition and a wide range of established relationships, and which serve a distinct purpose in the correlation of our knowledge. Properly used, with due recognition of their limitations, they are helpful, and suggest possibilities of research; misused, they may become mischievous. They now satisfy all known conditions; and that is a sufficient warrant for their existence.

U. S. Geological Survey, July 1, 1899.

ART. XXVIII.—*On Color-vision and the Flicker Photometer* ;
by OGDEN N. ROOD, Professor of Physics in Columbia
University. Part I.

IN the matter of color-vision, there seems to have been a tacit assumption that all persons could be divided into two classes, those with normal vision, and the color-blind. Holmgren's test with colored worsted classifies them in this way, and analogous tests give a like result. According to this view, the color-vision of persons free from color-blindness has generally been considered to be alike. Some time ago, for the purpose of comparing my own color-vision with that of others, an extensive set of experiments were made with the flicker photometer,* and while it turned out that not a single person agreed with *me*, it also was found that no two persons agreed with each other. These divergences were so large that it was impossible to attribute them to errors of observation, and the application to them of a control method showed them to have a real existence.

In making these determinations eleven persons were finally selected, most of them being young men, and all of them having claims to the possession of normal vision or varieties of it. Two were young women, and two, men in middle life. I started originally with fourteen persons, but was quickly obliged to reject three for previously unsuspected abnormality; two of these cases will be considered at the close of this article; the third, which is peculiar, is still under investigation. In comparing the eleven selected persons with myself, it was soon found that they could be divided into two classes with regard to their preception of green, five in one, six in the other, but as far as I could see, there was no especial reason for giving preference to one class above the other. It was accordingly decided to adopt the mean color-vision of the eleven, as representing, for the time being, standard human vision for color, and the divergence of each person from this standard was then calculated.

This standard color-vision is conveniently indicated by 100, in the cases of red, green and violet-blue light. 100 was also taken as the maximum attainable in each case, as these experiments did not deal with the general sensitiveness of the eye to light, but with its relative sensitiveness to light of different colors. That is to say, in the case of the color-curve of each person, the *highest* ordinate, whatever it may be, is set equal to 100, the others falling where the observations indicate on this assumption. Indeed there is no other way of making the

* See this Journal, Sept. 1899, p. 194.

calculations, without the aid of supplementary experiments of a totally different character. This much being premised, the tables given below will be intelligible. Classes A and B are given separately for the convenience of the reader, though as before said I do not know of any reason for giving preference to one over the other; indeed it will be noticed that they are more or less blended together by the cases of Wade, Parker and White.

Class A.			
	Red.	Green.	Violet blue.
Wade	97·7	97·4	100·
Trowbridge	100·	91·6	95·6
Dr. Hallock	100·	90·9	96·2
Miss Furness	97·9	90·8	100·
Curtis	90·5	86·6	100·
Miss M.	100·	81·6	99·

Class B.			
	Red.	Green.	Violet blue.
White	96·1	100	95·8
Parker	95·7	100	95·8
Dr. Dennett	93·8	100	91·5
Dr. Tufts	89·9	100	87·8
Dr. Day	82·9	100	93·3

It may be remarked that all the persons above mentioned are unusually abstemious in the use of alcohol, tea, coffee, and tobacco, and the person who is most deficient in red does not use these articles at all.

It is true that the above results have been obtained by the aid of a standard derived from only eleven persons, all, apparently, with what has heretofore been called normal vision: of course it would be desirable to extend the observations to a larger number of persons, but in the meanwhile it is quite evident that the standard here adopted is considerably better than if one of the eleven had been selected, hap-hazard, as a representative of normal vision. It also follows that anyone of the eleven, when furnished with his curve, becomes a secondary standard, and can correct his observations till they are in accord with the standard here adopted. These results also make it evident, that no one, man or woman, is qualified to do reliable quantitative color-work until his or her color-vision has been tested as above indicated. Certain discrepancies in the older determinations may find here a partial explanation, the remainder, of course, being due to the employment of the older photometric methods.

Below are the results for three cases of red color-blindness,

two of which were not previously suspected. All three persons were quite unable to stand the Holmgren worsted test.

	Red.	Green.	Violet blue.
J. Alsberg.....	30·3	88·1	100·
Mr. W.....	35·6	85·5	100·
Mr. O.	35·3	100·	93·9

Older persons appear to be more or less subject to another kind of defect in their color-vision, due, as Dr. Noyes suggests, to a yellow coloration of the crystalline lens. I have not studied the subject much, and can give the result of only one case: it was obtained by the use of the standard above described.

Red.	Green.	Violet blue.
100	77·2	72·

ART. XXIX.—*The Iodometric Determination of Gold*; by
F. A. GOOCH and FREDERICK H. MORLEY.

[Contributions from Kent Chemical Laboratory of Yale University—LXXXVIII.]

IN a recent attempt to measure small amounts of gold in solution by titrating with sodium thiosulphate the iodine set free in the action of an excess of potassium iodide upon auric chloride, Peterson* has been led to conclude that, on the average, one-half more thiosulphate is used up in changing the characteristic starch iodide blue to the faint rose color which precedes entire bleaching than is called for upon the theory that the thiosulphate is simply converted to the tetrathionate in the usual manner. Peterson explains the anomaly upon the hypothesis that, besides acting upon the free iodine, the thiosulphate is used up coincidentally by interaction with the aurous salt, formed in the reduction, with formation of a gold sodium thiosulphate on the type of the well-known silver sodium thiosulphate. The reaction of this hypothesis is in the nature of things most improbable, since there is no reason to suppose that the soluble double thiosulphate could resist the action of the free iodine which is present to the end—the appearance of the rose color,—and our study of the reaction of sodium thiosulphate upon the mixture of gold chloride and potassium iodide, the account of which follows, discloses no evidence of the consumption of more thiosulphate than is demanded by the usual theory, which postulates the simple formation of the tetrathionate by the interaction of the thiosulphate and free iodine.

It appeared in the course of our preliminary experimentation that, while practically similar results were obtained by adding the thiosulphate until the blue of the starch iodide had changed to rose, the indications were somewhat more concordant when the final rose color was developed by adding iodine to the solution from which the blue had been bleached to colorlessness by a slight excess of the thiosulphate.

It appeared, also, that the reduction of the auric salt, with the consequent liberation of iodine, is conditioned by the volume of the solution, the mass of the iodine present, and the time of action.

The following statement, in which each result is the average of several titrations in close agreement, shows the effect upon the immediate evolution of iodine brought about by adding varying amounts of water to the gold solution before introducing the iodide, and the effect of different amounts of iodide at different dilutions.

* Zeitschr für Anorg. Chem., xix, 63.

Sodium thiosulphate, N nearly $\frac{100}{100}$ cm ³ .	Potassium iodide.					Volume before the addition of Gold the thio- chloride. sulphate.	
	0.01 gm.	0.02 gm.	0.05 gm.	0.1 gm.	0.2 gm.	0.00087 gm.	cms.
	0.81	0.81	0.81	0.82	0.84	"	15
	0.77	0.78	0.80	0.81	0.81	"	25
	0.74	0.72	0.78	0.79	0.80	"	50
	0.61	0.61	0.68	0.76	0.79	"	100
	0.45	0.49	0.60	0.72	0.75	"	200

It is evident that for the smaller amounts of iodide the liberation of iodine decreases rapidly with the dilution. The larger amounts at the highest concentration show readings a trifle above the normal—perhaps because the well-known effect of concentrated solutions of a soluble iodide upon the delicacy of the starch end-color begins to appear. At volumes lying between the limit of 25^{cm³} and 50^{cm³} 0.1 gm. of potassium iodide is an appropriate amount to use; at a volume of 15^{cm³}, 0.01 gm. to 0.05 gm. of the iodide will do the work; and at lower dilutions, as will appear in the tabular statements to follow, even less of the iodide is effective.

In the series of experiments of which the details are given in Table I, use was made of a solution of pure gold chloride containing 0.8710 gm. to the liter—as determined by careful precipitation in the usual manner by ferrous sulphate, and by an alkaline solution of formaldehyde according to the method of Vanino.* A nearly centinormal solution of iodine was prepared by diluting to a liter 100^{cm³} of nearly decinormal iodine in potassium iodide carefully standardized against exactly decinormal arsenious acid. A nearly centinormal solution of sodium thiosulphate (containing 1.7012 gm. of Na₂S₂O₃ to the liter) was made by diluting to a liter 100^{cm³} of a nearly decinormal solution of that reagent which had been standardized carefully against the standard iodine prepared as described. The solution of potassium iodide employed contained 10 gm. of that salt in the liter.

In conducting the experiments, a convenient amount of the solution of gold chloride was drawn from a burette, potassium iodide was introduced in the amounts indicated (always several times the theoretical equivalent of the gold, and more than enough to dissolve the aurous iodide precipitated at first), a sufficiency of clear starch indicator was added, the starch blue was bleached by the thiosulphate, and the iodine was added until the liquid assumed a faint rose color. Upon the theory that potassium iodide sets free two atoms of iodine for every

* Ber. d. d. chem. Gesellsch., xxxi, 1763.

molecule of auric chloride (or every atom of gold) present, and that the thiosulphate acts only upon the free iodine to form the tetrathionate in the usual manner, every cubic centimeter of the thiosulphate solution used in the reaction after deducting the amount equivalent to the iodine introduced to get the end-color, should represent

$$\frac{197.3}{2(158.22)} \times 0.0017012 = 0.001061 \text{ gram. of gold.}$$

TABLE I.

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Plainly, these results accord reasonably with the theory that two molecules of the thiosulphate are the equivalent in this reaction of two atoms of iodine and one atom of gold. There is no evidence whatever of the excessive action affirmed by Peterson.

The strength of the standard solutions used in the experiments described was such that an error of 0.01^{cm}³ in reading the volumes used would correspond to an error of 0.00001 gram. of gold. It is not to be expected that such readings can be trusted ordinarily to a higher degree of accuracy than 0.02^{cm}³. In case all three solutions should be read to this limit of accuracy with the errors of all lying in the same direction, the summation of error would correspond to 0.00006 gram. of gold.

In the following experiments, therefore, solutions obtained by properly diluting those of the previous series were employed. The use of a more dilute solution of gold obviated the neces-

sity for diluting the mixture of gold chloride and the iodide before titrating with the thiosulphate. It was found, however, that when the $\frac{N}{1000}$ solution of iodine is employed a correction of 0.1cm^3 for volumes not exceeding 30cm^3 becomes necessary—the amount required to bring out the rose color in blank tests containing no gold. After the introduction of 0.1cm^3 of $\frac{N}{1000}$ iodine into a mixture of potassium iodide and starch indicator of volume not exceeding 30cm^3 , a single drop of the gold solution—equivalent to 0.000002 grm. of gold—gave a distinct rose color: before such adjustment of the solution five drops—equivalent to 0.000010 grm. of gold—were needed to develop the same color.

TABLE II.

Gold chloride = 0.0871 to 1 liter.

Sodium thiosulphate, nearly $\frac{N}{100}$ = 1.7012 “ “

Iodine, nearly $\frac{N}{100}$, = 1.3697 “ “

Solution of gold chloride not diluted before mixing with potassium iodide.

A

	AuCl ₃ taken. cm ³ .	KI taken. grm.	Na ₂ S ₂ O ₃ used. cm ³ .	Gold taken. grm.	Gold found. grm.	Error. grm.
(1)	10	0.01	0.83	0.00087	0.00088	+0.00001
(2)	10	0.01	0.83	“	0.00088	+0.00001
(3)	10	0.01	0.80	“	0.00085	—0.00002
(4)	10	0.02	0.84	“	0.00089	+0.00002
(5)	10	0.02	0.88	“	0.00093	+0.00006
(6)	10	0.02	0.82	“	0.00087	0.00000
(7)	10	0.02	0.88	“	0.00093	+0.00006
(8)	10	0.02	0.83	“	0.00088	+0.00001
(9)	10	0.10	0.80	“	0.00085	—0.00002
(10)	10	0.10	0.82	“	0.00087	0.00000
(11)	10	0.01	0.83	“	0.00088	+0.00001
(12)	9	0.01	0.73	0.00078	0.00077	—0.00001
(13)	8	0.01	0.65	0.00070	0.00069	—0.00001
(14)	7	0.01	0.58	0.00061	0.00061	0.00000
(15)	6	0.008	0.51	0.00052	0.00054	+0.00002
(16)	5	0.008	0.41	0.00043	0.00044	+0.00001
(17)	4	0.005	0.35	0.00035	0.00037	+0.00002
(18)	3	0.005	0.24	0.00026	0.00026	0.00000
(19)	2	0.003	0.21	0.00017	0.00022	+0.00005
(20)	1	0.003	0.10	0.00009	0.00011	+0.00002

TABLE II (continued).

B						
Gold chloride				= 0.0871 to 1 liter.		
Sodium thiosulphate, nearly $\frac{N}{1000}$				= 0.17012 " "		
Iodine, nearly $\frac{N}{1000}$				= 0.13697		
AuCl ₃ taken. cm ³ .	KI taken. gram.	Na ₂ S ₂ O ₃ used. cm ³ .	Gold taken. gram.	Gold found. gram.	Error. gram.	
(21)	10	0.01	8.39	0.000871	0.000890	+0.000019
(22)	9	0.01	7.45	0.000784	0.000790	+0.000006
(23)	8	0.01	6.30	0.000697	0.000668	-0.000029
(24)	7	0.008	5.50	0.000610	0.000583	-0.000027
(25)	6	0.008	5.12	0.000523	0.000543	+0.000020
(26)	5	0.005	4.23	0.000435	0.000449	+0.000014
(27)	4	0.005	3.38	0.000348	0.000358	+0.000010
(28)	3	0.003	2.55	0.000261	0.000270	+0.000009
(29)	2	0.003	1.71	0.000174	0.000181	+0.000007
(30)	1	0.003	0.90	0.000087	0.000095	+0.000008

These results run on the whole as regularly as could be expected, and the use of the dilute standard solutions is obviously of advantage.

In the practical application of any such process for the determination of gold, the elementary form of that metal is the natural starting point. To get the metal into solution with chlorine water or mixed hydrochloric and nitric acids is an easy matter, but the removal of the excess of the oxidizer by evaporation without reducing some auric chloride to the aurous form is difficult. We have found, however, that the free chlorine may be removed from a solution of auric chloride, without reducing the auric salt, by treatment of the solution with ammonia in excess, boiling gently, acidifying with hydrochloric acid and heating if necessary to redissolve the precipitate by ammonia, again treating with ammonia and heating, and once more acidifying. On the second addition of ammonia no precipitation usually takes place with the amounts of gold which we have thus handled, perhaps because enough ammonium chloride has been found to hold it up.

The following table contains determinations made with such a solution of pure gold leaf—tested gravimetrically as to purity.

Obviously, this method, which rests upon the hypothesis that sodium thiosulphate acts in the normal manner only upon the iodine set free by the interaction of gold chloride and potassium iodide, offers trustworthy means for the determination of small amounts of gold.

TABLE III.

Gold chloride made by dissolving 0.0104 grm. of pure gold in the manner described and diluting to 200^{cm}³.

Sodium thiosulphate, nearly $\frac{N}{1000}$, = 0.17012 to 1 liter.

Iodine, nearly $\frac{N}{1000}$ = 0.13697 " "

Potassium iodide = 10 grms. " "

Portions were treated with the potassium iodide without previous dilution.

	AuCl ₃ taken. cm ³	KI taken. grm.	Na ₂ S ₂ O ₃ used. cm ³	Gold taken. grm.	Gold found. grm.	Error. grm.
(1)	1	0.005	0.55	0.000052	0.000058	+ 0.000006
(2)	1	0.005	0.55	0.000052	0.000058	+ 0.000006
(3)	2	0.005	1.06	0.000104	0.000112	+ 0.000008
(4)	2	0.005	1.08	0.000104	0.000114	+ 0.000010
(5)	5	0.01	2.45	0.000260	0.000260	0.000000
(6)	5	0.01	2.50	0.000260	0.000265	+ 0.000005
(7)	5	0.01	2.45	0.000260	0.000260	0.000000
(8)	5	0.01	2.50	0.000260	0.000265	+ 0.000005
(9)	5	0.01	2.50	0.000260	0.000265	+ 0.000005
(10)	10	0.02	4.86	0.000520	0.000515	— 0.000005
(11)	10	0.02	4.85	0.000520	0.000517	— 0.000003
(12)	10	0.02	4.90	0.000520	0.000520	0.000000
(13)	10	0.02	4.80	0.000520	0.000512	— 0.000008
(14)	10	0.02	4.84	0.000520	0.000516	— 0.000004

ART. XXX.—*The Mineralogical Structure and Chemical Composition of the Trap of Rocky Hill, N. J.*; by ALEXANDER HAMILTON PHILLIPS, D.Sc.

Introduction.

THE Mesozoic trap rocks, or trap dikes of the eastern coast of the United States, are almost entirely confined to a comparatively narrow strip of country, in which the Triassic formation appears at the surface. The two seem to be so constantly connected, that almost every isolated Triassic area, however small, is accompanied with its corresponding intrusions of trap.

The Triassic strata of the Atlantic coast extend in a northeast and southwest direction from Nova Scotia to North Carolina, through an interrupted course, and are found more or less in isolated patches along the western portion of the coastal-plain, and lying next the older crystalline schists of the Appalachian range, into and through the border of which the trap dikes also extend.

In size, these dikes vary from a foot or so in thickness to such large masses as are represented by the Palisades of the Hudson. Their direction, especially of the larger masses, conforms in a marked degree to the strike of the strata in which they lie, and owing to their greater power of resisting erosion, they appear on the surface as parallel ridges, which mark the transition from the low level country of the coastal-plain to the higher foot-hills of the Appalachian Range.

Throughout this entire area of some twelve hundred miles in extent, the mineralogical composition of the trap is wonderfully alike, as has been pointed out from results of analyses of this rock from localities widely separated.^{1*}

The specific gravity of these traps varies, from data collected by J. D. Dana,² from 2.94, that of the Palisades, to 3.16, that of a specimen from North Carolina; while there are cases in which the specific gravity falls as low as 2.83.³ 3.16 still seems to be the maximum.

The mineralogical constituents were generally supposed to be magnetite, augite and labradorite. G. W. Hawes⁴ was the first to show the complex character of the feldspars, from analyses made of specimens of the West Rock, at New Haven, and of the New Jersey Palisades. Campbell and Brown later pointed out other complexities than that of the feldspars, and a specimen from Milford, N. J., is described as a hypersthene-diabase⁵; as well as an olivine-diabase from Virginia.

* See references given on p. 285.

Magnetite, augite and labradorite may be considered as the most widely distributed and characteristic minerals of the Triassic traps, and, from the constant occurrence of small percentages of P_2O_5 in all analyses, apatite might be added to these three. The above is, however, by no means a complete list of primary minerals which occur locally, for added to these, olivine, anorthite, hypersthene, biotite, pyrite, and zircon are local minerals, given here in the order of their frequency.

The minerals of contact and decomposition, or of secondary formation, are well known and have a well deserved reputation from their beauty and perfection of crystalline form; they have found their way into all collections.

Description of the Rocky Hill Dike, and its relation to the Sedimentary Strata.

In its relation to the sedimentary strata, the Rocky Hill dike is no exception to the rule, lying well up in the strata, which represent the Triassic beds, and especially so at either of its extremities.

The Triassic has been divided here into three divisions^e: the Stockton, Lockatong and Brunswick shales; the Stockton being the lower and older in the series, lying just above the crystalline gneiss.

The Rocky Hill trap extends for some fifteen miles in a northeast and southwest direction through these beds of shale, lying for the most part within the Brunswick shales, to the strike of which it seems to conform for about six miles west of the village of Rocky Hill, where it makes a slight curve, and breaks through the strata extending to a higher horizon in the Brunswick shales; at this bend the ridge reaches its highest elevation, Mount Rose possessing an elevation of 415 feet, as given in the New Jersey Geological Report. From this point it gradually declines in height eastward, until the ridge entirely disappears at the country level east of the Pennsylvania railroad. One mile east of Rocky Hill village it divides into two branches; one extends east, the other north towards Griggstown, this branch being much the smaller of the two in extent, and separated from the easterly one by a formation known as the Sand Hills. Whether these two branches are connected by a sheet of trap underlying the Sand Hills as suggested by N. H. Darton,⁷ produced by an upward folding of the trap is difficult to prove, although from consideration of the whole lay of the strata, this seems very probable.

The surface occupied by the trap is thickly strewn with large irregular, though somewhat rounded masses of rock in

different stages of decomposition. The resistance offered by the basic traps of this formation to atmospheric weathering is very marked, in contrast to acid dikes; the acid dikes weathering much faster than the enclosing sedimentary rocks,^s leaving long channels, while the basic traps are prominent as ridges. The soil lying between the surface boulders and derived from them by decomposition is never very deep. In quarries, that portion lying at the surface has a reddish appearance, caused by the oxidization principally of the ferrous iron contained in the augite. This surface weathering does not extend to depths much greater than ten feet, in the rock mass itself; individual crystals in macroscopic specimens from depths greater than this seem perfectly fresh. The disintegration reaches much greater depths along joints and cracks. In the quarry at the Hopewell end of the dike an entirely different decomposition has taken place, much of the rock mass here exposed is soft and chloritic in nature, and has taken up 3 per cent of water; some specimens show even more than this, and well crystallized calcite and zeolites appear in the cracks and joints.

In width the Rocky Hill dike does not vary much from a half mile. Along the Mount Rose road, which crosses it at a right angle, it measures 860 feet. Along the gorge of the Millstone River, which also cuts through it at Rocky Hill village at nearly a right angle, it measures 4000 feet, and if we take into consideration the dip of the enclosing strata, to which it seems to conform at these points, its thickness measured at right angles to the dip at Mount Rose would be 250 feet, at the Millstone 1200 feet. That the dip of the enclosing strata is conformed to, at least in the middle section of the dike, is proven, in lack of evidence shown by direct contact, by the baked condition of the shales lying on the north or upper side, in contrast to those lying on the south or under side. The shales lying on the north from near Griggstown to Mount Rose having been brought in close contact with the liquid magma, have been semifused and upon cooling crystallized in some cases, but generally developing spilositcs in large quantities. In particularly favorable localities, such as north of the canal bridge at Rocky Hill, the dark green crypto-crystalline nodules reach their largest size, being in some cases three-quarters of an inch in diameter. These nodules do not appear to exist at all on the south side of the dike, and the explanation seems to be, that the shales resting directly upon the molten mass have suffered far greater baking than those underneath, for if the dike were vertical we should expect an equal baking on both sides, which, indeed, is the case west of Mount Rose, where the trap dike no longer conforms to the strike of the

shales, but breaks up through them, its surface area becoming very much narrowed in consequence.

At several points in the fused shales well crystallized epidote and tourmaline have been found, and especially at the Griggs-town copper mine, where very perfect crystals of black tourmaline completely fill some specimens of the shale. They are hemimorphic, showing the hexagonal prism with fine longitudinal striations, terminated at one end by the rhombohedra (02 $\bar{2}$ 1) and (10 $\bar{1}$ 1), the antilogous pole being more complicated. Here also anygdaloid cavities were found, one of which was 1.3 inches in length, with walls thickly studded with well-formed crystals of epidote, calcite and a yellow mica, probably chalcodite.

Macroscopic Description.

At the village of Rocky Hill, the Millstone River cuts through the trap ridge at nearly a right angle, forming a gorge 150 feet deep; along the eastern side of this gorge the Rocky Hill Stone Storage Company has opened three quarries, located in different positions of the dike, as related to a vertical cross-section. No. 1 is near the lower side, 480 feet from the contact border; No. 2 is near the middle of the dike, 1350 feet from No. 1, and No. 3 420 feet from the upper contact and 1600 feet from No. 2. These distances are only approximate, as the upper and lower contacts cannot be made out definitely. Quarry No. 2 is the only one worked at present, rock being taken out and crushed for road and ballasting purposes. Each of these three quarries represents a different phase of the rock, not only in macroscopical appearance, but also in the chemical composition of the mineral constituents, as well as in the analyses of the rock as a whole.

Specimens near the contact with the shale have a very fine, granular, almost massive structure, appearing to the eye homogeneous, except here and there, where light is reflected from an almost microscopical cleavage face of a feldspar crystal; otherwise the boundary rock, and especially on the lower side, is a dark, slate-blue color, massive and compact, showing no cavities or schistose structure. Passing in from the crypto-crystalline border region, when quarry No. 1 is reached, the rock has assumed the characteristic texture of an ordinary dolerite; here it presents a coarse-granular appearance, in which its two prominent minerals, feldspar and augite, are easily distinguished; as the aggregation of feldspar crystals proceeds, the color of the rock is less dark, and specimens from quarry No. 2 appear much lighter than any others. Here the augite crystals reach a length of $\frac{3}{8}$ of an inch. In this region there is a well-defined schistosity developed, produced by the

parallelism of the long axis of the augite crystals. The excellent cleavage of these crystals gives a decidedly easy fracture along this direction, to the entire rock mass. This easy fracture is taken advantage of by the workmen in splitting out blocks for street paving.

There can be distinguished in the coarse variety, dark, irregular, highly lustrous though small aggregates of magnetic oxide of iron. The size of these aggregates increases with the coarseness of the specimen.

Scattered throughout the entire mass are very minute crystals of chalcopyrite, too scattered to form a factor in the analyses of the rock. In some rare localities they have been segregated into masses, as much as half an inch in diameter. It may be mentioned here that copper minerals are found at several localities along the contact of the trap and the shale, especially at Griggstown, where a small quantity of ore has been taken out in the form of silicate and carbonates.

The structure found in quarry No. 2 represents the conditions which are found throughout the greater portion of the dike, from the Millstone River westward. Eastward the coarseness decreases, due undoubtedly to the fact that erosion has not exposed the deeper, more central and coarser portions. Quarry No. 3 represents the maximum coarseness and differentiation of the rock's components, for here, as is afterwards shown from the analyses, the composition is the farthest removed from the original magma, as represented by the composition of the microcrystalline band along the contact. The aspect of the rock has changed, due to two primary causes. In the first place, this is due to the elongation of the diallage-like augite crystals, measuring often an inch, and occasionally two inches in length. With its excellent cleavage and metallic schiller, it forms a very striking feature, while the schistose arrangement marked in quarry No. 2 has been lost here, probably the pressure to which it was due having been removed or relieved by smaller secondary dikes, though a diligent search of the locality has failed to reveal them. There are some small dikes northeast of the Rocky Hill trap, though their connection with it is not apparent. Judging from the perfection of the crystals of diallagic augite, there could at the best have been no very great disturbance, as they have suffered but slight distortion, their long axis being but slightly curved, and showing no displacements.

In the second place, the color of the feldspar has changed from white to a very light flesh color, which certainly indicates a change in its nature, which is also brought out in the analyses. That portion of the dike which presents these characteristics is limited to a small area, and nowhere outside of quarry

No. 3, or its immediate vicinity, are crystals of like perfection and size found. It is also remarkably near the upper contact border, and judging from its differentiation, coarseness and crystalline perfection as compared with other portions of the dike, it must have been subjected to slower cooling, and has been the last portion to consolidate, or might have been in close contact with the source from which the molten magma was forced out, and consequently nearer the source of heat. This would explain the slower cooling, but not the difference in composition, which specimens from these three localities show.

The shales just above this point show an extensive baking, for it is here that the spherulites reach their maximum, both in number and size, indicating that they have been subjected to a more intense heat, or one of longer duration.

Microscopical Description.

Microscopically, the groundmass shows the absence of glass, and is therefore holocrystalline. In the finest grained portions the feldspars are present in the characteristic lath-shaped crystals, metasilicates lying between them, in the form of fine crystalline aggregates of grains or wedged-shaped anhedrons, each having a different crystallographic orientation.

This structure, with the absence of glass, following the classification of Iddings⁹ for these rocks, is that of a dolerite or diabase, in contrast to the basalts, in which glass is present in the groundmass.

Magnetite, being one of the primary minerals, and characteristic of these diabases, is found liberally represented in sections from all portions of the dike; and in those from the contact-band, subject to more rapid cooling and crystallization, magnetite is evenly distributed as fine irregular grains, showing no crystalline boundaries, except in a few cases where octahedral outlines appear. Since the magnetite is not found as inclusions in the feldspars, but is contained in everything else except in the apatite, the formation of the mineral in the magma has been subsequent to that of the feldspars. The conditions favorable for its separation have been of considerable duration, as the relative quantity contained in the dike has increased in sections from coarser specimens, as from quarry No. 3; here the masses of magnetite have reached such a size as to form a macroscopic feature of the rock. Some of these larger masses completely enclose feldspar crystals as well as apatite, which appears in hexagonal sections in an otherwise completely dark field of magnetite.

Qualitatively all the magnetite gives very strong reactions for titanium, and judging from this it must carry nearly if not

all the one per cent. or more of the titanite oxide found in the rocks.

While magnetite is one of the first minerals to separate from a magma on cooling, the relation of the magnetite to the other minerals in the sections, enclosing feldspars, apatite, and even augite, being wedged in between other crystals in the sections, would indicate that its separation has been a slow, continuous one, and since its relative quantity increases in that portion of the dike which we believe has been the last to consolidate, there have been changes in the magma favorable to this increase. From these facts we would conclude that the magma, after having been intruded between the sedimentary strata, was subjected to a very slow and gradual cooling, and possibly under high pressure, which would also tend to keep the magnetite in solution. That this cooling was slow, and that after injection the magma was subjected to little or no subsequent disturbance, is also brought out by the condition of the apatite crystals, which are everywhere present. In sections from the outer portions, apatite is represented by numerous slender but short needles, which increase in size until in sections from quarry No. 3 they reach a diameter of $.2\text{mm}$ and a length of 1.5mm before disappearing out of the section, being uninterrupted throughout their long axis and extending through adjacent minerals, both magnetite and feldspars. As these are the first crystals to form, any slight disturbance during the slow cooling would have been sufficient to break up this continuity.

Olivine.—The conditions favoring the separation of olivine in the Rocky Hill diabase have been very limited, as crystals of it are very few in number and confined to the border area, but these few present interesting facts when their method of decomposition is considered. They occur as rounded grains for the most part, but few showing an ill-defined crystalline form. The larger crystals, where fresh, are of a light green color, and show a good cleavage as well as irregular fracturing.

In their decomposition they have followed two distinct methods. The first, or earlier one, is by the formation of grains of magnetite, appearing as black granular strings, following all the cleavage cracks and irregular fractures of the crystals; and especially on the border, the black grains have been produced to such an extent as to surround each crystal with a decidedly dark band, and in the case of some of the smaller nodules, this secondary formation of iron oxides has proceeded so far, that the entire body of the crystal is nearly opaque, and might be mistaken for a mere collection of magnetite granules. This method of decomposition of olivine is described by Zirkel¹⁰ in connection with the olivine of gabbros, and furthermore he states that it is never found in connection

with the olivine of basalts. Prof. J. W. Judd,¹¹ in connection with the older peridotites of Scotland, concludes that it is a phenomenon which takes place only at a great depth from the surface, and consequently at considerable pressure. From this we may conclude that originally this trap was buried far below the surface at the time of its intrusion, and has since been elevated to its present position, and the strata originally covering it have been carried away.

The second method of the olivine decomposition is that generally found at the surface, in which an olivine rich in iron, such as this seems to be, by oxidation and formation of small scales of limonite and hematite, becomes dark yellow, brown or red. The greater number, and especially the smaller rounded grains, have become deeply colored by this formation of iron oxide, while the larger, some at least, are still perfectly fresh, with the exception of the magnetite grains. Their rounded shape is due to a partial resolution in the magma, as is shown by the corrosive cavities.¹² There are present, also, large inclusions of glass, so characteristic of olivine. The absence of serpentine as a decomposition product would also point to an olivine with large percentage of iron.

In size the olivines attain a maximum diameter of about .04^{mm}.

Augite.—The crystallization of the diallage-like augite is varied. In slides of the finer or diabase structure, the ground-mass is composed of a collection of microscopical crystals, with now and then a lath-shaped section of a larger augite lying among them. In sections at right angles to the *c*-axis the characteristic prismatic cleavage is well developed, as is also the cleavage parallel to the orthopinacoid; crystals from quarry No. 1 show a maximum extinction angle of 46°.

These diallagic crystals constantly increase in length as we pass in from the border; in quarry No. 2 they are 8 to 10^{mm} in length; in quarry No. 3 they reach their maximum length. They are all elongated in the direction of the *c*-axis, and the pinacoids are developed at the expense of the prism faces, giving them a flattened appearance. The color constantly deepens, and in reflected light they appear about black, except on cleavage faces where a characteristic schiller is developed. The cleavage faces parallel to the prism show the trace of a twinning plane parallel to the orthopinacoid, running directly through the middle of the crystals, each twin being equally developed. This twinning is very constant in the larger crystals, and between crossed nicols, in some instances, polysynthetic twinning is indicated along this line. In transmitted light, their color is uniformly brown, with little pleochroism. Extinction is undulatory, indicating a shell-like structure, the angle of extinction being greater for external than

for the internal layers. This angle constantly increases from the fine-grained crystals, where it is 46° , reaching a maximum of 58° in the larger crystals of quarry No. 3. Sections parallel to the vertical axis show a constant structure of fine striations; traces of interposition planes, parallel to the basal pinacoid. These striations appear on all sections which are parallel to the vertical axis, as running across, between the cleavage cracks. They do not appear on sections parallel to the base, neither as lines or dots, which would indicate that they are not fibres, but owe their origin to polysynthetic twinning parallel to the basal pinacoid. Their trace, on sections parallel to $\infty P \infty$, makes an angle of about 74° with the trace of the composition face of the twins twinned parallel to $\infty P \infty$, when the lines are symmetrical on either side. This would prove these lines to be traces of planes parallel to OP , as the angle β for monocline pyroxene is $74^\circ 10'$; these very fine interposition planes play an important part in the decomposition of the mineral, as well as in the production of the peculiar schiller. The great number of small inclusions contained in the crystals are symmetrical in regard to the axis, and fall into two groups; those parallel to the vertical axes, and those arranged along the twinning planes, parallel to OP . The inclusions are of the nature of cavities filled with hydrated oxides, formed by solution of the crystal body under pressure, as described by Judd, who infers that they are negative crystals, and mark the line of least resistance to solution, and therefore stand in the same relation to the body of the crystal as the etching figures do to the surface or faces. Of the two systems that one in which the long axis is parallel to the c -axis of the crystal offers the greater resistance to solution, and requires a higher pressure, consequently takes place at greater depths.

This system is the better represented of the two and is very characteristic of sections from the central and upper portions of the dike; they are considerably elongated, and occur in large numbers. If they are secondary formations it would add another proof, that this dike was formed at a considerable depth below the surface. Whether they are secondary formations is very difficult to determine. The matrix surrounding them has not been bleached as if the oxides of iron filling them had been drawn from their immediate vicinity. This is in decided contrast to other granular inclusions, evidently secondary products, found as a result of surface action, in which the body of the crystal presents a decided bleaching.

The formation of these secondary granules begins first at the margin and works its way toward the central portions of the crystal, following cleavage cracks and fractures, and especially along interposition planes running across between the cleavage

cracks; following this system, they form parallel lines of fine granules of magnetite, limonite, etc., which seem to be also an important factor in producing the schiller-like luster, and they would evidently be a result of surface action. These secondary granules are very numerous since the percentage of ferrous iron in all these crystals is very high.

As decomposition advances, other products are formed and become mixed with the oxide of iron granules, such as fibrous chlorite, biotite and epidote; even when this has reached such an advanced stage that the original crystal is replaced by a crystalline aggregate, the position of the fine interposition planes of the mother crystal is still marked by lines of dark granules. The oxidation of the large amount of iron contained in the diallage is the first step in the rock's decomposition and has commenced even before the clouding of the feldspars.

Biotite, as a primary mineral, is absent, and is found only as a secondary product derived from the decomposition of the diallage. It is present only in those slides which show the diallage in an advanced stage of decomposition; its formation begins after a considerable amount of the iron has been oxidized.

Quartz.—What has been said of biotite may also be said of quartz, to a great extent, with this exception, that in specimens from quarry No. 3 there are a small number of quartz grains which are evidently primary, judging from their size and the freshness of the surrounding crystals. Secondary quartz is formed in connection with the formation of chlorite in the decomposition of the diallage; this is best represented in the Hopewell quarries, where quartz granules can be picked out of the mass of chlorite.

Amphibole, in the form of hornblende, is represented in a few slides from the central portions of the dike, but is most frequent in all slides from quarry No. 3 and here stands in a very intimate relation and is closely connected with the history of the diallage, from which it has been derived by paromorphism. It occurs in two distinct varieties: one compact, yellow-brown in transmitted light, the other fibrous and light-green, both of which are very pleochroic. In the green variety, the ray vibrating parallel to *c* is decidedly bluish green; that parallel to *a* and *b* yellow. In the compact form, the pleochroism is shown only in shades of brown and yellow; the absorption is very marked, especially in the compact variety, and sections with the light rays vibrating parallel to *c* are very dark. The absorption in both varieties is as usual $c > b > a$. The prismatic cleavage is perfectly developed and is strikingly in contrast to that of the neighboring diallage crystals. The maximum extinction-angle measured from cleavage cracks in

the prism zone was 16° . The compact as well as the fibrous form exists as boundaries to the diallage¹³ with their long axes parallel. The fibres are limited to the outer portions of the diallage, while the compact is distributed as patches in the interior of some of the diallage crystals, as well. These interior patches would point rather to paramorphism than to decomposition as the agent to which the hornblende owes its origin. Neither variety would be considered as a primary component.

Feldspars.—In all slides from quarry No. 1 and the border region, the structure of the feldspars is eminently that which is so characteristic of the diabases, being ophitic in contrast to the irregular appearance of feldspar crystals marking the gabbro structure. Both of these structures are perfectly represented in different portions of the dike.

In sections of the finest grained specimens, which appear macroscopically to be almost homogeneous, the feldspars are always well formed, and are always present in lath-shaped sections; their average size is $.21^{\text{mm}}$ in length and $.046^{\text{mm}}$ in width, which will also give a good idea of the fineness of this diabase. Toward the center of the dike, the feldspar crystals constantly increase in size, and by the time quarry No. 1 is reached they have increased to $.5^{\text{mm}}$ in length and $.15^{\text{mm}}$ in width, still presenting very strongly the ophitic structure; in numerous cases, however, there is a strong tendency toward the granular, irregular, or gabbro structure. This is brought about by a shortening of the a -axis, parallel to which the lath-shaped crystals are elongated.

Twinning after the albite law is common, and generally the smaller crystals are composed of a single pair of twins. As the crystals increase in size, polysynthetic twinning after the albite law is the rule. The large angles of extinction on sections perpendicular to 010, rising to a maximum of 37° , coupled with the double refraction, would indicate a feldspar rich in calcium or one in which the ratio of anorthite to albite was high or of the composition of bytownite. The feldspars of quarry No. 2 upon the whole have a higher index of refraction, and the difference in the interference colors is very marked. The twinning is more extensive and many of the crystals show a decided compound nature. This is brought out by the lamellæ in the central portion of the compound crystals extinguishing at larger angles than the exterior bands, also by the interference colors of the different lamellæ. The central lamellæ are also much narrower, and the lath-shaped form is giving way to granular and irregular-shaped crystals in sections.

In the identification of the feldspars, samples of the powder separated with the Thoulet solution were used, and the angles

of extinction on the base in connection with the albite twinning striations or the prismatic cleavage were measured. In the sample with a gravity greater than 2.69, fragments showing the lath-shaped crystals with narrow striations clearly predominated over the fragments of the granular form of crystal with wide twinning laminations. The reverse of this was found to be the case in the sample separated with a gravity less than 2.69.

The compound nature of these five samples is indicated by the difference in the extinction-angles of the several laminae of which they are composed, so that the separation of feldspars of complex nature is at the best only a coarse assorting, in which the majority of particles will have a composition agreeing with the specific gravity, or will be homogeneous. The fineness to which each particle would have to be reduced to separate these interlaminated feldspars, is far beyond the practicability of separating them with the solution, owing to the slowness with which they settle. The angle of extinction measured on the base was found to vary from -27° to -4° ; the lamellae giving the larger angle were found to be the very narrow, more centrally located. These angles indicate that the analysis of this sample would lie between the composition of Ab_1An_6 on the one side and Ab_1An_1 on the other.²²

In the sample separated with a gravity less than 2.69, the fragments with the very narrow lamellae had disappeared. The angle of extinction was found in numerous cases to be almost parallel with the twinning striations, showing that the proportion of anorthite had decreased until the composition is possibly that of oligoclase or andesine. In quarry No. 3 the crystallization of the feldspars is very irregular, and complicated by an increase in the tendency to form, in addition to the twinning after the albite law, numerous twins after the Carlsbad law, showing both straight and irregular contact planes. Numerous patches exhibit the cross hatching produced by the combination of the albite and pericline twinning. The Baveno type is also present in frequent cases. The large masses of feldspar do not give distinct crystalline outlines, being moulded by the surrounding diallage crystals and magnetite, fragments of which they enclose. Their crystallization must have been either at the same time or after that of the diallage. These masses of feldspar preserve the same crystallographic orientation throughout, thus presenting the poikilitic structure common in gabbros.²³

A large proportion of the feldspars of this locality have become clouded and stained dark by the infiltration of iron from neighboring decomposing diallage; the cloudiness being produced by the first steps in kaolinization.

Chemical Analysis.

In the analysis of the rock, what seemed to be typical specimens from quarries No. 3 and No. 2, and a specimen from the microcrystalline contact region, were selected. These three specimens, it was thought, would represent the three stages in the trap so decidedly different in the development of its crystals, and would also give a good basis, by means of which the magmas from out of which they were crystallized might be compared. The specimen from the border was taken, as the magma must have consolidated upon contact with the sedimentary rock, or at least soon after injection between the strata, and can therefore be held to represent the composition of the entire mass at the time of its intrusion, or its original composition.

In specific gravity these specimens fall in the middle of the series observed in the Mesozoic trap. The average for the entire dike would be about 3. The densities of specimens collected at various localities along the ridge vary between 3.125, the density of a specimen from the Hopewell extremity, and 2.935, the density of one taken near the village of Rocky Hill. The density of the typical rock from quarry No. 2 was found to be 2.968; that of quarry No. 3, 3.023. These variations in density are no more than would be expected, caused by the local change, both in the composition and relative proportion of its primary minerals.

Analyses of the Rocky Hill Trap.

	I.	II.	III.	IV.	V.	VI.
	Quarry	Quarry	Contact			
	No. 3.	No. 2.	band.			
SiO ₂	56.78	50.34	51.46	52.1	52.53	52.37
TiO ₂	1.44	1.56	1.06	----	.32	.21
Al ₂ O ₃	14.33	15.23	13.98	16.7	14.35	15.06
Fe ₂ O ₃	5.76	2.82	2.66	----	5.93	2.34
FeO	9.27	11.17	8.92	12.7	5.45	9.82
MnO .....	.25	.14	----	----	trace	.32
CaO	5.26	9.61	10.49	10.8	10.27	7.33
MgO	1.58	5.81	7.59	3.2	7.99	5.38
Na ₂ O	3.43	2.93	4.75	2.3	1.87	4.04
K ₂ O	1.75	1.02		.8	.97	.92
P ₂ O ₅ .....	.36	.20	.17		.15	
					SO ₃ = .08	
H ₂ O above 110°	.10	.07	*	1.4 ignition	1.23	2.24
H ₂ O below 110°	.33	.19	----	----	----	----
	100.64	101.09	101.08	100.	101.14	100.03

* Unfortunately for direct comparison this specimen was dried at 150° before it was analyzed, but the percentage of H₂O must have been small.

Analyses IV to VI of Mesozoic trap are given for comparison; IV is an analysis of Rocky Hill trap, by G. H. Cook; V, by F. A. Genth, from York Co., Pa.; VI, Trap rock at Meriden, Conn., by J. H. Pratt.¹⁵

Analyses V and VI represent the average composition of the Mesozoic trap of the Atlantic coast, and by a comparison with these analyses, the variation of the Rocky Hill trap from the mean will be apparent. The most important points to be noted are: first, that the Rocky Hill trap is high in alkalis and especially so in potassium, which also becomes concentrated locally in quarry No. 3. This high percentage of alkali is a factor which exercises an important influence in the composition and formation of the various feldspars.

Second, the percentage of iron is high, especially the ferrous iron. The iron as well shows a decided concentration in No. 3. This high amount of ferrous iron produces a diallage remarkably high in FeO, as the analyses will show. While the TiO₂ is very high in comparison with the two analyses given, there are other analyses in which TiO₂ is present in equally as high percentages. In the West Rock, New Haven, there is 1.41 per cent of TiO₂.¹⁶

In the separation of the various mineral components for analysis, the magnetite was taken out with a small electromagnet, the strength of which was not sufficient to attract the diallage; though diallage in which magnetic granules had developed as a result of decomposition and oxidization of the ferrous iron was removed. After the magnetic portions were removed, the remainder was separated with the Thoulet solution. The diallagic augite separated at the highest specific gravity of the solution; after this trials were made at various stages of dilution, until the specific gravity of the feldspars was reached. Up to this point very little material could be separated, and this, when examined with the microscope, was found not to be homogeneous.

Neither in specimens from No. 2, or from No. 3, was the amount separated above the specific gravity of 2.72, that is after magnetite and diallage had been removed, very large. In the further separation of the feldspars, the solution was diluted to a specific gravity of 2.69, the theoretical density which would separate the two species of feldspars, labradorite on the one side, and andesine on the other¹⁷; then again diluted to a density of 2.60, separating the anorthoclase from albite. In order to obtain as pure sample as possible of each, for analysis, each specimen was put through the solution several times. While the specific gravities of the feldspars overlap each other to a great extent, still these portions separated will give an idea of their molecular variation in different positions

of the dike, i. e. at different steps in the crystallization of the magma.

In the analysis of the diallage-like augite the sample used in No. 2 was separated at the highest specific gravity of the solution. That used in No. 3 was selected by hand, as the crystals were quite large.

Analyses of Diallagic Augite.

	No. 2.	Ratio.	No. 3.	Ratio.	IV.*
SiO ₂ -----	47.72	.795	48.54	.809	50.71
Al ₂ O ₃ -----	3.44	.014	5.50	.053	3.55
					(MnO)
Fe ₂ O ₃ -----	5.93	.037	2.77	.017	.81
FeO-----	18.34	.254	21.25	.295	15.30
CaO-----	11.40	.205	10.97	.196	13.35
MgO-----	12.89	.320	7.67	.191	13.63
Na ₂ O-----	.86	.013	3.10	.039	1.48
K ₂ O-----	.37	.003			
Ignition----	.00	----	.82	----	1.17
	100.95		100.62		100.00
No. 2.	R ₂ O : RO : R ₂ O ₃ : SiO ₂				
	.016 : 779 : .051 : 795				
No. 3.	R ₂ O : RO : R ₂ O ₃ : SiO ₂				
	.039 : 682 : .07 : 809				

From the chemical composition these two pyroxenes lie between the molecule of hedenbergite (CaFeSi₂O₆) on the one side and diopside (CaMgSi₂O₆) on the other, of which they are isomorphous mixtures¹⁸; combined with these is a small proportion of the alkali-bearing pyroxene (NaFeSi₂O₆). The magnesia-bearing molecule separates out first at higher temperatures, decreasing the percentage of Mg in the rock as a whole; this has been carried to such an extent, that when No. 3 is reached, this locality being the last to consolidate, the percentage of MgO has been reduced to 1.58. The magnesia content has been a decreasing factor from the beginning of crystallization; decreasing from 7.59 per cent in the contact, to 1.58 per cent in No. 3. As the pyroxene is the only magnesia-bearing mineral present, with the exception of olivine in the contact region, the greater portion of this change in per cent of magnesia present is caused by the variation in the pyroxene molecule. The change in the iron-bearing molecule is not so clear, it being obscured by the magnetic oxides, which increase along the same direction as the ferrous component of the pyroxene; what has been lost by the lack of magnesia in

* Augite from West Rock, New Haven, Proc. U. S. National Museum, vol. iv, p. 132.

the magma has been made up in ferrous iron and alkalis. The tendency is, then, to form pyroxene at the border, rich in magnesia, of the composition of $\text{CaMgSi}_2\text{O}_6$ when the magma is rich in magnesia, or of the composition of $\text{CaFeSi}_2\text{O}_6$ when the magma is rich in iron.

The calcium in the pyroxene does not seem subject to much change.

There has been an increase in the alkali-bearing molecule, aemite, as the amount of SiO_2 has increased. This increase of the aemite molecule as the acidity of the magma increases, is in accord with the experiments of F. Becke.¹⁹ He points out that the aemite molecule takes part in the composition of monoclinic pyroxene, crystallizing from magmas with a percentage of SiO_2 of 50 or above. With the increase of 6 per cent of SiO_2 from No. 2 to No. 3 there is a decided increase of K_2O and Na_2O found in the pyroxene. Campbell and Brown⁵ have shown that in this Mesozoic diabase rich in MgO , where it reaches an amount equal to 12 per cent or more, the orthorhombic pyroxene appears as the mineral hypersthene. We would not expect an orthorhombic pyroxene to appear in the Rocky Hill diabase, as the proportion of $(\text{FeO} + \text{MgO}) : \text{CaO}$ in the analysis showing the highest percentages of these, is as 1·7:1, a proportion of FeO and MgO far below the ratio at which it has been found necessary for these to be present, in order that they, in crystallizing, should form an orthorhombic pyroxene. The molecular relation of $(\text{MgO} + \text{FeO}) : \text{CaO}$ must be as 3:1 or greater.²⁰ This high proportion of $\text{MgO} + \text{FeO}$ is only locally reached in this diabase, and for that reason it is to be expected that the metasilicate is almost invariably some form of the monoclinic pyroxene.

Analyses of Feldspars from Quarry No. 2.

	I.		II.		III.		IV.	V.
	Gravity greater than 2·69.		Gravity < 2·69.		West Rock, N. H. ⁴ Gravity > 2·69.	Gravity < 2·69.	Gravity 2·703.	Gravity 2·659.
SiO_2 ---	53·84	·899	62·26	1·037	52·84	60·54	53·7	62·
Al_2O_3 --	29·30	·287	21·87	·216	28·62	24·11	29·6	24·
Fe_2O_3 --	·81	·005	·54	·003	1·52	1·14	----	----
CaO --	10·08	·180	6·53	·116	11·81	9·15	11·8	5·3
MgO --	·28	·007	·15	·003	·46	·27	----	----
Na_2O --	5·31	·085	7·98	·128	2·38	4·11	4·9	8·7
K_2O ---	1·16	·012	1·20	·012	·86	1·06	----	----
Ignition	·44	---	·32	----	1·06	·59	----	----
	101·22		100·85		99·75		100·97	

I. Gravity > 2·69. Ratio of

$$\text{R}_2\text{O} : \text{RO} : \text{R}_2\text{O}_3 : \text{SiO}_2 = \cdot 097 : 187 : \cdot 292 : \cdot 899.$$

In this feldspar the albite molecule is to the anorthite molecule as 1:1+ or the feldspar is a normal labradorite, which agrees well with the optical properties as found in quarry No. 2.

IV gives the theoretical percentage composition of a labradorite of the proportion of 3 molecules of albite to 4 molecules of anorthite²¹.

II. Gravity <2.69. Ratio of

$$R_2O : RO : R_2O_3 : SiO_2 = .140 : .119 : .219 : 1.037.$$

This would represent a feldspar of the composition of albite to anorthite in the proportion of 5:2+ and would be that of an oligoclase.

V represents the composition and gravity of an oligoclase of the proportion of 3Ab:1An.²¹

Feldspars from Quarry No. 3.

	I.		II.		III.		IV.
	Gravity	> 2.69.	Gravity	< 2.69.	Gravity	< 2.60.	Gravity
		Ratio.		Ratio.		Ratio.	2.577.
SiO ₂ -----	66.84	1.110	71.68	1.195	66.28	1.104	66.79
Al ₂ O ₃ -----	17.98	.176	15.02	.147	16.79	.164	19.36
Fe ₂ O ₃ -----	2.60	.016	2.48	.015	1.60	.010	.91
CaO-----	4.02	.071	3.86	.068	.71	.012	.80
MgO-----	.48	.012	.12	.003	.13	.003	.13
Na ₂ O ₃ -----	5.46	.088	5.52	.076	9.76	.057	7.34
K ₂ O-----	1.72	.018	1.37	.014	5.31	.056	4.95
Ignition----	.72		.00		.49		
	99.82		100.05		101.07		100.28

$$\begin{aligned}
 \text{I. } R_2O : RO : R_2O_3 : SiO_2 & \left. \begin{array}{l} 106 : 83 : 192 : 1.110 \end{array} \right\} = 9 \text{ Ab} : 3.5 \text{ An.} \\
 \text{II. } R_2O : RO : R_2O_3 : SiO_2 & \left. \begin{array}{l} 90 : .71 : 162 : 1.195 \end{array} \right\} = 5 \text{ Ab} : 2 \text{ An.} \\
 \text{III. } R_2O : RO : R_2O_3 : SiO_2 & \left. \begin{array}{l} 213 : 15 : 174 : 1.104 \end{array} \right\} = 6 O_1 : 22 \text{ Ab} : 1 \text{ An.} \\
 & K_2O : Na_2O \\
 & 56 : 157
 \end{aligned}$$

IV is the composition of an anorthoclase.²⁴ In the analyses of the feldspars from quarry No. 3 it was impossible to get good samples, from the fact that they are considerably decomposed and stained by infiltration of iron; in addition to this all the quartz found in this locality will be included in II, and for that reason the percentage of SiO₂ here runs up to 71. While the above analyses cannot strictly be taken to represent the composition of pure feldspars, they will represent, however, the relation of K₂O, Na₂O and CaO in the feldspars of this position in the dike, and will also enable us to make a comparison with the feldspars of No. 2 crystallizing earlier.

Here the normal feldspar is an andesine or oligoclase, replacing the normal labradorite of quarry No. 2. In order to get an estimate of the quantity of each mineral compound of quarry No. 2 and No. 3, a sample of each was taken, crushed finer than $\frac{1}{100}$ inch, and the dust washed out, then separated with the magnet and solution, with the following results, as the magnet was strong enough to remove the secondary oxide of iron granules formed by the decomposition of diallage: in getting the total per cent of diallage this magnetic portion must be considered, but is given separately here.

	Quarry No. 2.	Quarry No. 3.
Magnetite	4.1	6.
Magnetic	3.6	9.7
Diallage	45.6	41.
Feldspar, G. > 2.69	32.2	23.1
Feldspar, G. < 2.69	14.3	13.4
Feldspar, G. < 2.60	0.	6.5

The decrease in the density of the feldspars from No. 2 to No. 3, or their increase in acidity is clearly shown by the above figures. The total feldspars in No. 2 is 45 per cent; 69 per cent of this is denser than 2.69, and 31 per cent lighter than 2.69, while it all falls before the solution reaches the density of 2.60. The total feldspars in No. 3 is 43 per cent, 53.7 per cent is denser than 2.69, and 46.3 per cent below the density of 2.69; of this 67.3 per cent is denser than 2.60, while 32.7 per cent is below the gravity of 2.60.

In the crystallization of the feldspars, the tendency is to form the anorthite molecule at the border region, but that has not been reached, as the optical properties of the crystals in this region are those of a feldspar of the composition of bytownite, a feldspar richer in CaO than any of the samples analyzed; this is also substantiated, as the analyses of the rock in this region indicates a 10 per cent increase in CaO. From the bytownite molecule the amount of CaO has gradually decreased until in quarry No. 3, the last region to consolidate, a feldspar almost free of CaO has been formed, with a large percentage of K₂O. Thus the feldspars of the Rocky Hill dike present a complexity far greater than has yet been noted in connection with the Mesozoic trap.

Conclusion.

1st. The Rocky Hill trap, from its holocrystalline nature, would be classed as a dolerite.

2d. The border region possesses the ophitic development of its plagioclase; if the small amount of olivine present be considered, it would present the structure and composition of an olivine diabase.

3d. The slow cooling to which it has been subjected coupled with tendency of the anorthite molecule to separate at a higher temperature, has concentrated the more acid feldspars in the portion last to consolidate, to such an extent that its mineralogical composition is almost that of a diorite.

4th. From the character of the decomposition of the olivine, and the solution cavities in the diallage crystals, the intrusive nature of this dike is without doubt, as this must have taken place at considerable depths from the surface, and under very heavy pressure.

John C. Green School of Science, Princeton University,
New Jersey, June, '99.

Literature Cited.

¹ For analyses see: G. H. Cook, *Geology of New Jersey*, 1868; G. W. Hawes, *Trap Rocks of the Conn. Valley*, this *Journal*, 3d series, vol. ix; H. D. Campbell and W. G. Brown, *Geol. Soc. of Am.*, Bull. 2, 1891, p. 346; Dr. F. A. Genth, 2nd, *Geol. Survey of Pa.*, Report on progress in York and Adams Co., p. 120.

² J. D. Dana; this *Journal*, 3d series, vol. ix, p. 191.

⁴ G. W. Hawes, *Proc. U. S. National Museum*, vol. iv, 1881, p. 132.

⁵ H. D. Campbell and W. G. Brown, l. c., p. 341.

⁶ See *New Jersey Geol. Report* for 1896, p. 34.

⁷ N. H. Darton, *Bull. U. S. Geol. Sur.*, No. 67.

⁸ E. C. E. Lord, *Am. Geologist*, vol. xxii, No. 6.

⁹ J. P. Iddings, this *Journal*, 3d ser., vol. xxxi.

¹⁰ *Zeitschr. d. d. Geol. Ges.*, xxiii, 1871.

¹¹ J. W. Judd, *Quart. Jour. Geol. Soc.*, xli, 1885, pp. 381 and 382.

¹² H. C. Lewis, *The Genesis and Matrix of the Diamond*.

¹³ G. H. Williams, *Bulletin* No. 38, *U. S. Geol. Survey*.

¹⁴ W. H. Winchell, *Determinations of the Feldspars*, *Am. Geo.*, vol. xxi, p. 31.

¹⁵ *Mineral Resources of the U. S.*, 18th, p. 958.

¹⁶ This *Journal*, vol. ix, 1875, p. 327.

¹⁷ Dana's *System of Mineralogy*, p. 327.

¹⁸ G. Tschermak, *Ueber Pyroxene und Amphibole*, T. M. M., 1871-17.

¹⁹ F. Beche; *Experimentelle Untersuchungen über die Bildung der Minerale in Magma*, T. M. M., xviii, p. 124.

²⁰ J. H. L. Vogt, *Beiträge zur Kenntniss der Gesetze der mineralbildung in Schmelzmassen*, etc., Kristiania, 1892.

²¹ Dana's *System of Mineralogy*, p. 327.

²² See Iddings-Rosenbusch, p. 300.

²³ E. H. Williams, *Jour. of Geol.*, vol. i, p. 176.

²⁴ Dana's *System of Mineralogy*, p. 324, No. 8.

ART. XXXI.—*Some Analyses of Italian Volcanic Rocks*; by
HENRY S. WASHINGTON. I.

DURING the past two years I have made a number of analyses of Italian volcanic rocks, with the intention of incorporating them in a general article on the subject. As, however, other work has come up which will delay this indefinitely, it has been decided to publish them. Isolated analyses of rocks, without discussion of their relations to those of other connected types, are of little use. But they may prove of service to others investigating this region, and personally I would like to clear out this pigeon-hole.

Trachytes of the Phlegrean Fields.—The material composing the cone of Monte Nuovo, which was formed in 1538, is largely pumice and lapilli, but blocks of dense lava from a flow are found in a quarry on the southern slope, and it is from these that material was taken for analysis.

The rock is compact and very fine-grained, with a rough feel. The color is ash gray, with streaks of lighter gray. A few small glistening phenocrysts of alkali-feldspar are visible.

Under the microscope specimens vary considerably, but all belong to the Ponza type of Rosenbusch. The structure is hyalopilitic trachytic. Long slender prisms of alkali-feldspar are abundant, often split and branching as has been described in the case of some Ischian trachytes.* They are elongated parallel to the axis *a*. Small elongated crystals of ægirine-augite and grains of magnetite are present in less amount. All these, with dusty grains, lie in an isotropic glass-like ground-mass, which is usually colorless, but often a light brown, especially in patches. This base gelatinizes readily with HCl, and must be largely composed of the sodalite molecule, since it is the only constituent which could carry the notable amount of Cl found. I could find no trace of the anorthite and olivine mentioned by dell'Erba,† nor of the leucite spoken of by vom Rath‡ as having been found by G. Rose.

The specimen of the Monte Cuma trachyte was obtained from the large quarries at the west foot of the ancient acropolis. It is similar in appearance to the preceding, showing also a eutaxitic structure, though here the streaks are darker, and minute pyroxene phenocrysts are common.

Microscopically it differs considerably from that of Monte Nuovo. Prismatic phenocrysts of alkali-feldspar, elongated

* H. S. Washington, this Journal (4), i, p. 375, 1896.

† dell'Erba, Boll. Com. Geol. Ital., 1894, p. 197.

‡ Vom Rath, Zeitschr. d. d. Geol. Ges., xviii, p. 613, 1866.

parallel to \hat{a} , are abundant, their borders tending to shade off into the groundmass. Smaller, longish crystals of a pale green, very slightly pleochroic ægirine-augite are very abundant. Few, if any, of the separate individuals of ægirine mentioned by Rosenbusch* could be seen. The groundmass proper is composed of small rude laths and anhedra of alkali-feldspar, with grains of magnetite and ægirine-augite. Interspersed with these are small, colorless, isotropic anhedra, which gelatinize with HCl and stain readily. These must be referred to sodalite, which the analysis shows is present to the extent of about ten per cent. No glass base could be found and the specimen analyzed is quite holocrystalline. A dense, black, glassy obsidian, carrying many feldspar phenocrysts, is also found at the locality in small amount.

Vom Rath speaks of sodalite in the groundmass as “unvollkommen ausgeschieden,” and describes the sodalite which occurs in the crevices of the rock. He also mentions a scapolite-like tetragonal mineral as very abundant in the groundmass, and, from his analysis, comes to the conclusion that it has the composition of oligoclase.† My microscopical exami-

	I	II	III	IV	V
SiO ₂	60·33	59·79	61·71	59·47	61·23
TiO ₂	trace	trace	----	----	----
Al ₂ O ₃	18·74	19·71	16·85	17·24	18·42
Fe ₂ O ₃	2·84	2·95	4·27	4·33	----
FeO	1·29	1·08	----	----	4·55
MnO	trace	trace	trace	----	----
MgO	0·38	0·36	0·99	0·99	0·34
CaO	1·15	1·19	1·51	3·10	1·81
Na ₂ O	7·15	6·79	7·50	6·17	10·82
K ₂ O	7·30	7·10	4·36	8·01	2·62
H ₂ O	0·56	0·24	1·05	1·07	0·16
Cl	0·43	0·53	0·65	1·03	0·78
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	100·17	99·74	98·89	101·41	100·73
O = Cl ...	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	0·11	0·13	0·16	0·24	0·18
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	100·06	99·61	98·73	101·17	100·57

- I. Trachyte, Monte Nuovo. H. S. Washington anal.
 II. Trachyte, Monte Cuma. H. S. Washington anal.
 III. Monte Nuovo. Abich anal. Abich. Vulk. Ersch., 1841 p. 39. Recalculated in Roth. Gest. Analysen, 1861, p. 18, No. 9.
 IV. Monte Nuovo. Rammelsberg anal. Roth. Gesteins-Analysen, 1861, p. 18, No. 10.
 V. Monte Cuma. Vom Rath anal., op. cit., p. 610.

* Rosenbusch, Mikr. Phys., ii, 1896, p. 750.

† Vom Rath, op. cit., pp. 608, 612.

nation does not substantiate these observations, nor, from a chemical standpoint, is such an assumption necessary, as will be seen on discussion of the analyses. Vom Rath also describes and figures a fayalite-like olivine which occurs in the crevices. Its occurrence resembles that of fayalite in obsidians of Lipari, described by Iddings and Penfield.*

My two analyses (I and II) resemble each other very closely and are typically trachytic in most features. SiO_2 is about 60, which is rather low for trachytes and approaches the silica content of the phonolites. Al_2O_3 is normal; iron oxides, magnesia and lime are low, with Fe_2O_3 notably higher than FeO in accordance with the presence of the ægirine molecule. The alkalis are high, amounting together to 14 per cent, and molecularly Na_2O surpasses K_2O (the ratios being 1.47 and 1.45), so that both rocks must be held to belong to the sub-group of soda-trachytes.

The two analyses by Abich and Rammelberg are chiefly of historical interest, since they are obviously at fault in many particulars. That of vom Rath is better, but suffers from a peculiarity elsewhere observed in his rock analyses, viz: too high soda and too low potash.† It was this, together with his higher lime, which led him to infer the peculiar composition of the mineral mentioned above, which may be referred to sodalite, or possibly to marialite. The mineralogical composition of the Monte Nuovo rock cannot be satisfactorily determined, owing to the presence of glass. That of the Monte Cuma trachyte, however, which is holocrystalline, calculates out very nicely from the data given by the analysis and the microscope.

Orthoclase	42.2
Albite	34.4
Sodalite	11.1
Diopside	4.9
Ægirine	6.5
Magnetite	0.9

100.0

Trachytes of Ischia.—Of these rocks three analyses were made. They are all so well known that a detailed petrographical description seems superfluous. That from Monte Rotaro is the black vitreous rock containing sheaf-like ("keraunoidal") alkali-feldspars already mentioned. The Monte Marecocco lava is light gray with many large phenocrysts of alkali-feldspar, a typically trachytic groundmass of feldspar laths, diop-

* Iddings and Penfield, this Journal (3), xl, p. 75, 1890.

† Cf. H. S. Washington, Journ. Geol., v, pp. 351, 357, 1897.

side, ægirine and magnetite grains, and little or no glass. No sodalite could be found, though it is undoubtedly present. The Arso rock is the well-known black one with numerous feldspar phenocrysts. It is notable through its small though constant content of olivine.

	I	II	III	IV
SiO ₂	61·62	61·88	60·77	61·49
TiO ₂	0·87	0·69	----	----
Al ₂ O ₃	18·24	18·21	19·83	20·02
Fe ₂ O ₃	2·36	2·19	4·14	3·11
FeO	1·28	1·38	2·43	2·72
MnO	trace	trace	trace	0·01
MgO	0·56	0·61	0·34	0·52
CaO	1·44	1·15	1·63	1·88
Na ₂ O	5·77	6·89	4·90	3·39
K ₂ O	7·60	8·72	6·27	7·13
H ₂ O	0·78	0·37	0·24	0·46
Cl	0·15	0·30	----	----
P ₂ O ₅	----	----	trace	0·02
	<hr/>	<hr/>	<hr/>	<hr/>
	100·67	100·39	100·55	100·75
O = Cl	0·03	0·07		
	<hr/>	<hr/>		
	100·64	100·32		

I. Trachyte, Monte Rotaro. H. S. Washington anal.

II. Trachyte, Marecocco. H. S. Washington anal.

III. Monte Rotaro. Fuchs anal. Min. Petr. Mitth., 1872, p. 232.

IV. Marecocco. Fuchs anal. Min. Petr. Mitth., 1872, p. 229.

The two analyses (I and II) resemble each other very closely, except in the alkalis, though the total amount of these is the same. They are typical trachytes rich in soda, and are practically identical with those of the Phlegrean Fields, as was to be expected from the microscopical examination. The rather high TiO₂ is to be noted, as well as the Cl lower than in the preceding. They resemble on the whole the analyses of Fuchs, though his alkalis are considerably lower. It is probable that his alkalis are too low, since calculation shows that about two per cent more are needed to satisfy the SiO₂ and Al₂O₃ present. Analysis II, of the holocrystalline Marecocco trachyte, calculates out as follows. It seems probable that sodalite is rather too high, since it was not seen in the sections.

Orthoclase	39·5
Albite	47·1
Sodalite	4·7
Diopside	4·6
Ægirine	1·4
Magnetite	2·7

100·0

Analyses of the Arso lava are given below. Mine agrees fairly well with that of Fuchs, though there are certain differences, notably in the alkalis. His analysis of the scoria of this eruption, from Le Cremate, is lower in SiO_2 and higher in Al_2O_3 , but otherwise resembles that of the main part of the flow. Abich's analysis differs in several particulars from the others, and is inserted only for the sake of completeness.

This rock differs markedly from the other trachytes of Ischia, which, as Fuchs has shown, have a very uniform composition. It is much more basic, showing lower SiO_2 and alkalis, and higher FeO , MgO and CaO . The sections also reveal

	I	II	III	IV	V
SiO_2	56.75	57.73	54.83	61.03	57.91
TiO_2	1.24	-----	-----	-----	0.65
Al_2O_3	18.37	17.85	20.17	17.21	15.79
Fe_2O_3	2.22	4.44	4.77	4.84	6.81
FeO	3.04	3.90	3.86		0.01
MnO	trace	-----	-----	0.17	0.23
MgO	2.02	1.77	1.93	2.07	1.66
CaO	4.68	3.65	4.12	1.43	2.99
Na_2O	4.85	3.67	3.04	4.64	6.01
K_2O	5.92	7.65	7.38	7.16	7.27
H_2O	0.18	0.09	0.46	0.56	0.34
Cl	0.11	-----	-----	-----	0.60
P_2O_5	-----	trace	-----	-----	0.01
	<hr/> 99.38	<hr/> 100.85	<hr/> 100.56	<hr/> 99.11	<hr/> 100.27
$\text{O} = \text{Cl}$	0.03				0.14
	<hr/> 99.35				<hr/> 100.13

- I. "Ciminite," Arso, Ischia. H. S. Washington anal.
- II. Ditto, Arso. Fuchs anal. Min. Petr. Mitth., 1872, p. 230.
- III. Scoria, Le Cremate. Fuchs anal., op. cit., p. 231.
- IV. "Ciminite," Arso. Abich anal., Vulk. Ersch., 1841, p. 44.
- V. Sodalite-Trachyte, Monte Santo, Naples. Johnston-Lavis anal. Geol. Mag. (III), vi, p. 77, 1889.

the presence of some olivine and considerable basic labradorite. The rock, therefore, is not a typical trachyte, and was placed by me among the group of ciminites recently described.* It, however, does not contain as much MgO and CaO as these do normally, and might better be considered as transitional between them and the normal trachytes.

In a recent paper† Rosenbusch describes the minerals lining the crevices of this rock, which include alkali-feldspar, sodalite,

* Jour. Geol., iv, p. 834, 1896 and v, p. 351, 1897.

† Rosenbusch, Ueber Euktolith, etc., Sitz. ber. Akad. Wiss., Berlin, 1899, p. 111, note 1.

magnetite, biotite, augite, hypersthene and apatite. He remarks that this association, with the chemical and mineralogical characters of the rock, points conclusively to its relationship with the monzonites and essexites.

In connection with this rock it is interesting to note the composition of the sodalite-trachyte described by Johnston-Lavis, an analysis of which is given in V. The rock occurs west of Naples, near the Phlegræan Fields. It carries sodalite and hornblende, and, although it is not stated to contain olivine, in chemical composition it resembles very much the Arso rock, indicating a similarity in composition and differentiation of the magma at the two centers.

General Relationships.—This is not the place for a general discussion, but a few words may be devoted to the relationship of the rocks whose analyses have just been given to those of the other Italian volcanoes. The apparently justifiable assumption is made that these analyses fairly represent the composition of the rocks of the Phlegræan Fields and Ischia.

It is well known that the main line of Italian volcanoes has erupted rocks which are characterized chemically by high potash and lime, and that leucitic rocks are abundant.* It has also been shown that the rocks of this line belong to two main groups: the leucitic rocks, which are either basic (leucitites and leucite-tephrites) or intermediate (leucite-trachytes), and latites† (intermediate between trachytes and andesites or basalts), characterized by the presence of both orthoclase and plagioclase. In all these rocks the ratio of K_2O to Na_2O is constantly greater than unity, sometimes much so, and CaO is also high.

It is seen from the analyses given in the preceding pages that at Ischia and the Phlegræan Fields the rocks are chemically quite distinct, Na_2O being here constantly higher than K_2O , CaO being low, and leucite absent, or at least very rare.‡ They also tend to be rather high in SiO_2 .

While they differ from the rocks of the peninsula, they show certain analogies with the volcanic rocks of the islands which lie along the west coast of Italy,—those of Capraia,§ the Ponza Islands,|| the Lipari Islands,¶ and perhaps Etna** and the Val

* Cf. Journ. Geol., v, p. 376, 1897.

† Ransome, this Journal (4), v, pp. 355, 372, 1898.

‡ Leucitic rocks have been observed as blocks in tuff at Monte di Procida and one or two other places in the Phlegræan Fields. They are not abundant, and their relations with the main trachytic rocks are uncertain.

§ H. Emmons, Q. J. G. S., xlix. p. 129, 1893.

|| Doelter, Denkschr. k. Akad. Wiss. Wien, xxxvi, p. 1, 1875.

¶ Cortese and Sabatini, Descrizione delle Isole Eolie. Rome, 1892.

** v. Lasaulx in vom Waltershausen der Ætna, Leipzig, 1880, ii, pp. 425 ff. Ricciardi, Gazz. Chim. Ital., xi, p. 149, 1881.

di Noto in Sicily.* It is impossible here to go into a description of all these, for which the reader may turn to the references given. It must suffice to state that at Capraia we find andesites, at the Ponza and Lipari† Islands rhyolites, trachytes, latites and a few basalts, while at Etna‡ and Val di Noto there have been erupted only normal basalts of a fairly uniform composition. From the analyses of the rocks of these localities it is evident that they differ also chemically from those of the Bolsena-Vesuvius line, Na_2O being higher than K_2O (except in the rhyolites), though here also CaO is apt to be rather high.

Consideration of these facts leads to the conclusion that the rocks of Ischia and the Phlegræan Fields are related rather to those of the other islands than to those of the main Bolsena-Vesuvius line, and, while the data at hand are perhaps insufficient, I would express the view that they are not genetically connected (at least in an immediate way) with the closely adjacent rocks of Somma and Vesuvius.

The idea that a volcanic fracture-line exists west of the Italian peninsula was first broached by Pilla in 1842, supported by Doelter and Suess, expressed in a somewhat modified form by Ponzi, and has lately been taken up by Ricciardi.§ This last writer bases his conclusions partly on stratigraphical observations, but largely in a chemical way on the amount of SiO_2 in the various rocks.

That the amount of SiO_2 alone is not a proper nor sufficient basis on which to compare rocks of various regions is a fact that will scarcely be disputed by any petrographer. But from a broader point of view, embracing all the chemical and mineralogical characters of the various rocks, as well as from other, topographical, vulcanological and stratigraphical considerations, it would seem that the conclusion is justified that a volcanic fracture-line exists west of the coast of Italy and parallel with it, extending from Capraia, through the Ponza Islands, Ischia and the Phlegræan Fields, the Lipari Islands, and ending probably in Sicily at Etna and Val di Noto.

* Ricciardi, Gazz. Chim. Ital., xl, p. 171, 1881.

† It may be remarked that I have been able to find no good analysis of the well known rocks of these islands, with the exception of one of an apparently abnormal type described by Hobbs (Bull. Geol. Soc. Am., v. p. 599, 1893), those of Abich (Vulk. Ersch., 1841, pp. 25, 62) and of Baltzer (Zeit. d. deut. geol. Ges., xxvii, p. 36, 1875) being too obviously incorrect to merit consideration—a striking instance of the imperfection of our chemical knowledge of igneous rocks.

‡ Johnston-Lavis (Boll. Soc. Ital. Micro. Acireale, i, p. 26, 1888) has detected leucite in one of the basalts of Etna and Bäckström (Geol. Fören. Förh., xviii, p. 155, 1896), in rocks from Volcanello.

§ Ricciardi, Sull' Allineamento dei Vulcani Italiani. Reggio-Emilia, 1887. References to the other authorities cited may be found in this paper, as also a map.

The main vulcanological fact on which this conclusion rests is the similarity between the two lines in the order and direction of extinction along them. Space is lacking for detailed statement, but in both we find the volcanic activity dying away from north to south. Thus the volcanoes of Bolsena and Viterbo are older than those of the Alban Hills, where eruptions took place not much anterior to the earliest Roman times, and perhaps also during the Roman Republic. At the Ernici and Rocca Monfina the evidence is uncertain, but at the southern extremity there is the still active volcano of Vesuvius.

Similarly along the western line we find to the north the much denuded remains of old volcanoes at Capraia, Elba and Giglio. At the Ponza Islands the original forms are better preserved, though extensively denuded. At the Ischian region the forms are more perfect and activity is almost ended, as shown by the eruptions of the Solfatara, Monte Nuovo and Arso, and other facts. At the Lipari Islands we find also the remains of large volcanoes, and activity is still kept up to a certain extent at the small vents of Vulcano and Stromboli.* At Etna alone, near the extreme south end of the line, do we find a typical volcano, in a comparatively perfect state and in full activity,—comparable with Vesuvius.

It may also be noted that there seems to be a tendency for the later lavas to be more basic than the earlier, as has been pointed out in general for the Bolsena-Vesuvius line,† and as may be exemplified by the rocks of the Alban Hills, Vesuvius, Stromboli‡ and Etna.

That the petrographical provinces of the Bolsena-Vesuvius line and of the groups of Ponza, Ischia, the Lipari Islands and Etna are quite distinct is well known,§ but it is less generally supposed or accepted that a well marked line exists—now largely covered by the waters of the Mediterranean—which is parallel to the other and quite distinct from it, and that the rocks of Ischia and the Phlegræan Fields are not genetically connected with those of the neighboring Vesuvian vent.

In this connection it may be suggested as a tentative hypothesis that another parallel fracture-line is to be found to the southwest, which extends from the small islets of Linosa and Lampedusa, southwest of Malta, through Pantellaria to Sardinia. Concerning the first two islets our information is of the scantiest, it being only known that they are volcanic.|| Rosen-

* Cf. Bonney, *Volcanoes*, 1899, pp. 198–201.

† Cf. *Journ. Geol.*, v, p. 376, 1897.

‡ Cortese and Sabatini, *op. cit.*, p. 84. The rocks of Vulcano are also generally basic, but those of the last eruption are rather acid. (*Op. cit.*, p. 114.)

§ Cf. Bonney, *Volcanoes*, p. 197.

|| Scrope, *Volcanoes*, 1862, p. 345.

busch* has pointed out the close resemblance between the pantellerites of Pantelleria and the commendites of San Pietro on the southwest coast of Sardinia, which, as well as the other rocks of Pantelleria, are high in Na_2O .† At the volcano of Monte Ferru‡ in Sardinia Doelter found the rocks to be trachytes, phonolites and basalts (with some leucite-basalts), which, according to his analyses, show Na_2O (molecularly) uniformly higher than K_2O , and in some cases very high.

It would seem, then, from these rather insufficient and summarily given facts, that we have in the Italian district three parallel volcanic lines. The latest, along the peninsula, is characterized chiefly by high K_2O , as well as high CaO , and by the presence of leucite. The next, that of the islands along the west coast, is also high in alkalis but with Na_2O rather higher than K_2O , and without leucite. The third, which lies far out in the Mediterranean, and which is possibly the oldest, is much higher in Na_2O and seems to be characterized by the presence of peculiar soda minerals, such as ænigmatite and ægirine, nepheline also occurring in places. The relations of the three main centers exterior to these lines, those of the Euganean and Berici Hills and Monte Vulture, are uncertain and need not be discussed here.

Aug. 1, 1899.

* Rosenbusch, Mikr. Phys., ii, 1896, p. 614.

† We cannot determine this point in regard to the other rocks of San Pietro, as Eigel (Min. Petr. Mitth., viii, p. 73, 1886) unfortunately did not determine the alkalis separately.

‡ Doelter, Abh. Akad. Wiss. Wien., xxxviii, p. 41, 1878.

ART. XXXII.—*Mineralogical Notes: Melonite(?)*, *Coloradoite*, *Petzite*, *Hessite*; by W. F. HILLEBRAND.

IN a suite of tellurides from the Mother Lode region in California, collected by Mr F. L. Ransome, of the Geological Survey, I have been able to identify a nickel telluride (melonite?), a mercury telluride (coloradoite?), besides petzite and hessite.

Melonite?

Several specimens from the old Stanislaus mine,* the original source of Genth's melonite† (Ni_2Te_3 ?), but now included with the Melones and other claims under the name Melones mine, showed plainly a nickel telluride of reddish white cast of color like that of bismuth,‡ thickly scattered in grains and showing pronounced cleavage and a brilliant luster. A concentrate was prepared by the aid of cadmium-boro-tungstate solution, and this was then laboriously hand-picked by the aid of a powerful glass. There was certainly more than one foreign mineral present, but identification was not possible with exception of a little gold and petzite. The chief impurity was a silver mineral, presumably hessite. If so, the analyses seem to indicate also native tellurium. A perfectly pure article could not be extracted because of difficulty in sometimes distinguishing the foreign minerals from the one sought, but it was hoped that an analysis of both the selected and rejected portions would permit of calculating the composition of the nickel mineral with considerable certainty on the reasonable assumption that no impurity had been removed in relative excess over the other or others.

* Mr. Ransome has kindly furnished the following notes:

"This mine is situated on the south slope of Carson Hill, Calaveras Co., just above Robinson's Ferry, and has not been worked for several years. There is no prominent vein at this point, the ore being very irregularly distributed, and occurring in small nearly horizontal stringers in dark clay slates of Carboniferous age with nearly vertical dip. This mine has long been known as a source of interesting tellurides, and Dana, in the sixth edition of his *System of Mineralogy*, cites petzite, calaverite, melonite, and altaite as occurring here. The other ore minerals are pyrite and galena, the latter in small quantities. The ore-bearing stringers are filled with quartz, or a mixture of quartz and calcite as a gangue. The rich masses of tellurides appear, however, to be usually associated with calcite (or dolomite). The melonite of specimen No. 16 shows at least one perfect cleavage, resembling in the thinness of the resulting laminæ the cleavage of the micas. The cleavage faces are usually somewhat curved, and possess a splendid metallic luster. (The cleavage can best be detected by carefully scraping thin folia from such a brilliant surface with a sharp knife point.) The color of the cleavage faces is pale bronze-yellow."

† Long *o* accented.

‡ Under a lense and to the unaided eye in certain lights the color appears more bronze-yellow.

The analyses below represent the composition of (*a*) the rejected, (*b*) the original, and (*c*) the selected material. Analysis (*b*) is given chiefly because of the cobalt determination, the nickel being probably a little high. Although but 0.22 and 0.13 grams respectively were available for the analyses (*a*) and (*c*), the data are believed to be more trustworthy on the whole than those of (*b*), hence the figures under (*d*) have been obtained by calculation based on (*c*) and (*a*) only, after reducing them to 100. Under (*e*) is shown the theoretical composition of NiTe_2 . Small amounts of iron, traces of copper, and perhaps of one or two other elements are omitted, besides the $\frac{3}{4}$ –2 per cent of gold and petzite that remained unattacked by cold dilute nitric acid in which the nickel mineral is readily soluble.

The specific gravity of (*b*) at 22.5 was 7.72, which is probably higher than the true density of the pure nickel telluride.

	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i> NiTe_2
Te	75.29	77.72	80.75	81.40	81.29
Ni	15.71	17.16	18.31	18.60	18.71
Co .....		.10			
Ag	8.44	5.09	.86		
	<hr/> 99.44	<hr/> 100.07	<hr/> 99.92	<hr/> 100.00	<hr/> 100.00

If hessite and native tellurium constitute the foreign admixture, the mineralogical composition of (*a*) and (*c*) is shown to be as follows:

	<i>a</i>	<i>c</i>
NiTe_2	84.44	97.89
Hessite	13.51	1.38
Tellurium	2.05	.73
	<hr/> 100.00	<hr/> 100.00

There is here indicated a considerable selective separation of the foreign minerals, since the relative proportions of tellurium and hessite are very different in the two mixtures, but the amounts operated on were so small that a very slight actual error in a determination might give rise to this change in the relative proportions of impurities without affecting materially the ratios found for the components of the nickel telluride. The three analyses taken together point unmistakably to NiTe_2 as the formula for the latter mineral. The question then arises, is this Genth's melonite, or is it a new mineral? Genth found

Te	73.43
Ni	20.98
Ag	4.08
Pb .....	.72
	<hr/>
	99.21

from which, after deducting hessite, altaite, and free tellurium, he deduces the formula Ni_2Te_3 , requiring Te 76.49 and Ni 23.51.

The difference between this and my own analyses is too great to admit of bringing them into accordance, yet I am indisposed to believe that two minerals are represented, for both occurrence and appearance are opposed to such a view. The present mineral is from the same source as Genth's, its physical characteristics, so far as ascertainable, coincide with those of melonite, and it is called melonite by the people at the mine. Melonite was considered by Genth to be hexagonal on the strength of its eminent cleavage and the observation of a single microscopic six-sided plate. Mineralogically a hexagonal form in the pyrite group, assuming this mineral to belong there, is not to be looked for, but the evidence in favor of hexagonal crystallization is too meager to permit this to be used as an argument one way or another.

Coloradoite?

One small specimen from the Norwegian mine showed in dolomite, petzite, hessite, and a mercury telluride. Superficially the latter was not to be distinguished from the accompanying petzite and hessite, and it was in insufficient amount to admit of analysis for the determination of its formula. It, however, gave the tests noted by Genth for the original coloradoite from Colorado, and in addition the following characteristic may be noted. On heating with strong nitric acid it becomes coated with a white insoluble salt of mercury, which retards further action of the acid.

It is in all probability coloradoite, and if so this is its second known locality of occurrence, though I have been informed that a mercury telluride has recently been found in Western Australia.

Petzite.

One specimen of petzite from the Norwegian mine gave such an abundance of pure material that an analysis seemed desirable.

The results were as follows :

		Ratios.	
Au	25.16	1.98	1.00
Ag	41.87		3.04
Te	33.21		1.00
Se	trace		
Mo .....	.08		
	<hr/>		
	100.32		

Approximate specific gravity at 23° C. 8.925. The molybdenum may exist as sulphide. The ratios lead almost exactly to the formula Au_2Te , $3\text{Ag}_2\text{Te}$.

Hessite.

In conclusion may be given an analysis of hessite from a new locality, San Sebastian, Jalisco, Mexico, the material being received from Mr. Frederic Chisolm.

Specific gravity at 26° C. 8.24

Ag	61.16
Te	36.11
Pb	1.90
S, Fe, Zn .....	.83. (difference)
	<hr/>
	100.00

Laboratory of the U. S. Geological Survey, June, 1899.

ART. XXXIII.—*Note on Epidote and Garnet from Idaho*; by
CHAS. PALACHE.

IN the fall of 1898 Messrs. C. L. Whittle and Wm. Beals, Jr., presented to the Harvard Mineralogical Museum a suite of mineral specimens collected by them in the Seven Devils Mining District, Idaho, chiefly from the Peacock and White Monument mines. The ore of these mines is argentiferous chalcocite and bornite; these specimens, however, show but little ore material, being composed almost wholly of the associated vein minerals, among which were determined: (1) from the Peacock Mine—epidote, almandine garnet, quartz, chrysocolla, malachite, brochantite, hematite, and chlorite; (2) from the White Monument Mine—calcite, malachite, melaconite, grossularite garnet, and epidote; (3) from the Copper Key Mine—andradite garnet.

The Peacock Mine was the source of the powellite first described by Melville;* the specimens were therefore carefully searched for that mineral but none was found.

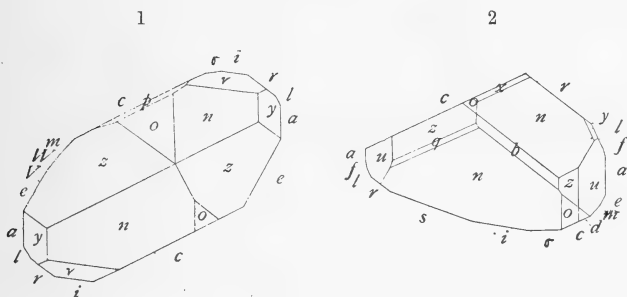


FIG. 1. $c(001)$, $a(100)$, $m(102)$, $W(305)$, $V(405)$, $e(101)$, $\sigma(\bar{1}03)$, $i(\bar{1}02)$, $r(\bar{1}01)$, $l(\bar{2}01)$, $z(110)$, $o(011)$, $p(016)$, $n(\bar{1}\bar{1}1)$, $y(\bar{2}\bar{1}1)$, $\eta(\bar{2}\bar{1}2)$.

FIG. 2. $c(001)$, $a(100)$, $b(010)$, $e(101)$, $m(102)$, $f(\bar{3}01)$, $l(\bar{2}01)$, $r(\bar{1}01)$, $s(\bar{2}03)$, $i(\bar{1}02)$, $\sigma(\bar{1}03)$, $z(110)$, $u(210)$, $o(011)$, $n(\bar{1}\bar{1}1)$, $x(\bar{1}\bar{1}2)$, $d(111)$, $q(\bar{2}\bar{2}1)$.

Epidote.—Epidote is the most abundant and most interesting mineral present. It is in well developed crystals lining the walls of cavities in massive epidote. The crystals are dark green in color and often of large size, the largest collected being two inches in length and breadth. Mr. Whittle saw a cavity in which a large number of perfect crystals upwards of a foot in length had been destroyed by the miner's pick.

The crystals have the normal epidote habit, prismatic parallel

* W. H. Melville, *this Journal*, xli, 1891, page 138.

to \bar{b} , and are generally flattened parallel to the basal plane so that lense-shaped cross-sections are common; they are invariably implanted on an end of the orthoaxis, \bar{b} . The majority of the crystals are terminated simply by $n(\bar{1}11)$, sometimes together with $b(010)$, and in the orthodome zone show $c(001)$, $i(\bar{1}02)$, $r(\bar{1}01)$, and $a(100)$. A few crystals, however, showed a much richer series of forms as seen in figs. 1 and 2, which are orthographic projections on the clinopinacoid and reproduce the distortion of the crystals.

Twinning was observed on several crystals according to the usual law: twin plane $a(100)$. In one crystal the twinning was repeated, two narrow lamellæ intervening between the two principal individuals.

Many of the crystals exhibit a strong tendency to scale off in concentric shells parallel to all the crystal faces. This was particularly noticeable in the crystals figured above, even the smallest faces preserving their luster and permitting good measurements after the surface layers had been removed. The shelly structure sometimes gives rise to a brilliant iridescence on the faces of the crystal and is generally associated with a bleaching of the color, presumably due to surface alteration.

Some of the epidote crystals are imbedded in quartz of later growth, the latest deposit in the cavities. A single specimen from the Decorah Mine showed such imbedded crystals of a pale green epidote which were exceptional in being doubly terminated.

The epidote is in places largely changed to a scaly chloritic material which was not further examined.

Garnet.—The garnet from the Peacock Mine is almandite, probably the same as that analyzed by Melville* from the same locality. It is in light to dark brown, completely developed, and very symmetrical crystals showing the forms $d(101)$, $p(211)$, and sometimes $s(321)$. They are imbedded in glassy copper-stained quartz from which they easily separate, leaving beautifully sharp casts.

A second type of garnet is found in the Peacock Mine specimens. Rough crystals an inch or less in diameter show a pronounced dodecahedral form, the edges slightly truncated by the icositetrahedron (211). The centers of the crystals are of a dark brown garnet substance; but the exterior is uniformly coated with a shell of clear quartz $\frac{1}{2}$ mm in thickness conforming in minutest detail to the form of the garnet crystal. A thin section through such a crystal showed that the quartz in one of these shells formed but a single crystal, and it appears to represent an original crystallization controlled in the disposition of

* Loc. cit., p. 138.

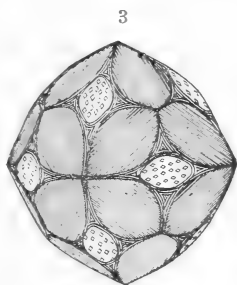
its material by the garnet crystal. Outside of the quartz is in many instances a similar coating of light green iridescent epidote and here and there thin plates of hematite are arranged between the layers of quartz and epidote. Calcite has also formed similar layers in some crystals and where afterwards removed by solvents leaves the crystals cavernous. The surfaces of the garnet crystals, whether coated with quartz or epidote, are smooth and plain and the effect on looking at an unbroken crystal is as of pseudomorphs of these two minerals after the garnet.

In specimens from the White Monument Mine, crystals of cinnamon-brown grossularite garnet showing only the form $p(211)$ are associated with a little epidote in an impure limestone. In these garnets layers of crystalline calcite are interpolated as in the last described crystals, with the difference that here the outer layer is of garnet substance.

Crystals of brown andradite garnet from the Copper Key Mine are notable for the etching which they have undergone. The forms originally present were $d(101)$ and $p(211)$ in almost equal development and perfectly symmetrical.

But as shown in fig. 3, the crystals have been much rounded by deep corrosion of all the edges, the solvent action having been greatest at the ends of the trigonal axes where uneven facets have been produced. Shallow rounded grooves replace the edges between d and p and a rounding of the angles at the ends of the axes gives in some cases an approximation to a cube face. The etch facets would give no measurable reflections but their position shows that they are in part trisoctahedrons and in part hexoctahedrons. The faces of both d and p still retain a brilliant luster, but the former are marked by beautifully sharp and symmetrical etch pits of rhombohedral outline, their edges parallel to the dodecahedral edges of the crystal; and the faces of p are grooved quite deeply parallel to the same edges.

A large specimen of vein material from the White Monument Mine consists of large cleavage rhombohedrons of calcite, each of which serves as a core to a spherical layer of radial fibrous calcite. The curved outer surface of these layers is a drusy one formed by sharp calcite rhombohedrons, which in its turn is coated over with a thin layer of quartz crystals. The interspaces between the spheroidal masses are filled with a mixture of dead black melaconite and green chrysocolla with a small amount of malachite.



Chrysocolla and malachite occur throughout the specimens as coatings on epidote or other crystals and in tiny veinlets which penetrate all the interstices of the other vein minerals.

Brochantite was found in several specimens in slender transparent emerald-green prisms or in radial-fibrous aggregates interspersed among the epidote crystals.

Hematite has been already mentioned as forming thin plates parallel to faces of the larger garnets; similar plates are found in the massive epidote and in quartzose portions of the vein.

Mineralogical Laboratory, Harvard University.

ART. XXXIV.—*On Thermoelectricity in Certain Metals*; by
LUDWIG HOLBORN and ARTHUR L. DAY.

[Communication from the Physikalisch-Technische Reichsanstalt, Charlottenburg, Germany. Laid before the Königlich Preussische Akademie der Wissenschaften, Berlin, July 20, 1899.]

IN connection with the investigation of the gas thermometer at high temperatures and the application of thermo-elements of the platinum metals to the comparison of its results, the need of a law which should accurately express the relation between the electromotive force developed by the latter and the temperature became strongly felt. Theoretical considerations led us to carry the research further, and include the lowest available temperatures as well; thus the range of the investigation became so broad that the behavior of thermo-elements was shown in a much clearer light than heretofore, as will be seen from the following brief sketch of the results.

Avenarius, as is well known, was the first to show that the electromotive force of a thermo-element, expressed as a function of the temperature, approximated very closely to a parabola, and this result has been confirmed for various temperature ranges by Tait, Knott and MacGregor, and Noll. Up to the present time, however, the agreement can be said to be satisfactory only between 0° and $300\text{--}400^{\circ}$, and even here several metals show considerable irregularities. Attempts have even been made recently to apply logarithmic formulæ where the difference in temperature between the junctions was large.

The thermo-elements which we have investigated have not, to be sure, followed the law of Avenarius in every case over the entire measured temperature domain, but within very wide limits the agreement is so astonishingly exact that the failure of the law to apply further can only be regarded as an evidence of some change in the condition of the metal investigated at that point—perhaps due to the absorption of gases. The great range of temperature to be covered by this investigation made it only possible to include metals which remain chemically unchanged at high temperatures, i. e., the platinum group together with gold and silver. Thanks to the kind assistance of the firm of Heräus in Hanau and the chemical laboratory of the Reichsanstalt, especially Prof. Mylius, we were able to lay much emphasis upon the chemical purity of the metals investigated.

One of the best means of testing the purity of a metal is often the measurement of its electrical resistance. This has

been done in this case; in fact one of the metals—gold*—offers a remarkable example of the effect of slight impurities upon the temperature coefficient of the resistance.

In connection with the pure metals several alloys were also investigated but offered no exception to the application of the law.

The metals, with the exception of iridium and rhodium, were in the form of drawn wires of 0.6^{mm} diameter; these two were rolled out into narrow rectangular strips slightly larger than the wires. Wires as well as strips were brought to a bright glow electrically before being used and their homogeneity tested by connecting their ends with a galvanometer while lying in the electric oven, the temperature being maintained first at 500°, then at 1000°. Only the two gold wires Au₀ and Au₁ showed any considerable effect, an electromotive force amounting to 60 microvolts being here obtained. The palladium wires behaved somewhat peculiarly, showing an electromotive force of about 150 microvolts when first laid in the oven at 1000° and half as much at 500°; this decreased in a short time to less than a third of the original value. There is an evident connection between this and a phenomenon conspicuous when the wires were first heated as above mentioned; they did not glow uniformly at once, but several sharply defined dark stretches were noticeable which slowly diminished in length and disappeared after some ten minutes, the wire then glowing quite uniformly.

The electric oven consisted of several concentric tubes of clay separated by air spaces, the innermost tube carrying a coil of nickel wire which could be freely heated to 1300°.

The elements were heated in a porcelain tube which extended through the oven without being in contact with it except on the outside where the cold projecting ends were supported. The hot junction lay in the middle of the oven, and the wires, carefully insulated from each other, were carried out at the ends to the cold junctions (0°).

For the temperature measurement a platinum—platin-rhodium thermo-element was used which had been compared with the gas thermometer between 0° and 1000°. Assuming that one junction is maintained at 0° while the other is heated to t° , it is possible to express the electromotive force of the element between 300° and 1000° as a quadratic function of t within the limits of the errors of observation. Above 1000° the temperatures were obtained by extrapolation of this function.

With this standard element the other elements were severally compared, the four wires being melted together at the hot

* This gold wire (Au₀ of the table) had already shown surprising behavior in its electrical and thermal conductivity—Jaeger and Diesselhorst, Sitz. Ber. Berl. Akad., 1899, p. 719.

junction and the electromotive force of any particular metal then being measured with respect to the pure platinum which with the platin-rhodium formed the standard element and indicated the temperature of the hot junction.

The temperature was held as nearly constant as possible at intervals of about 50° and the electromotive force of the metals in various combinations measured; the values for the exact intervals contained in the table being obtained from these by graphical interpolation.

The table contains first the coefficients a^* , $100\ b$, and $10000\ c$ of the formula

$$e = -a + bt + ct^2$$

the thermoelectric potential difference (e) being expressed in microvolts; second, the temperature limits t_1 and t_2 , within which the formula has been found to apply; third, the mean temperature coefficient α of the electrical resistance between 0° and 100° ; and finally, the differences (calculated — observed) expressed in degrees between the values obtained from the formula and the corresponding observed values of the electromotive force. Where the formula no longer applies the differences are enclosed in parentheses.

It will be seen that with the exception of palladium, the Avenarius formula applies between a definite comparatively low temperature and the highest temperature observed, the difference between observed and calculated values being in the mean less than 1° , smaller, in fact, than the differences observable in the same element under different experimental conditions. In the case of palladium, however, two distinct equations are distinguishable, the one for the lower temperatures (below 400°) and the other for the higher (above 600°), and between the two lies a domain of 200° where neither equation applies. Otherwise the agreement between observed and calculated values is nearly as good as with the other elements except in the case of the alloy 90 Pd, 10 Pt, where at the lower temperatures the sensitiveness is very small. This element in particular is also the only one having a minimum within the temperature domain of these observations, the change in direction falling within the limits where neither of the equations applies.

Regarding the difference between the value of the constants a , b and c for various specimens of the same material, no very useful conclusions can be drawn from the material at hand. In the case of gold the value of a seems to decrease with

* It is evident that when the formula contains a constant term, it cannot apply downwards as far as 0° . If, as is nearly always the case, this constant is negative (for which reason it appears with the negative sign in the formula), it indicates that the curve is too steep to pass through 0° .

	Au ₀ -Pt	Au ₁ -Pt	Au ₂ -Pt	Ag-Pt	Rh ₁ -Pt	Rh ₂ -Pt	Ir-Pt	90 Pt, 10 Ru -Pt	
a	644	398	388	0	169	228	84	367	a
10 ² × b	684.9	876.9	892.0	589.1	700.0	734.4	670.0	922.9	b × 10 ²
10 ⁴ × c	96.8	84.4	83.4	132.0	68.0	66.8	60.0	15.6	c × 10 ⁴
t ₁	300°	300°	300°	0°	200°	250°	100°	300°	t ₁
t ₂	950°	1050°	1050°	950°	1250°	1300°	1200°	1300°	t ₂
α	0.00214	0.00389	0.00397	0.00405	0.00440	0.00446	0.00394	—	α
0°	—	—	—	0.0°	(-24°)	(-31°)	(-12.5°)	(-40°)	0°
50	(-56°)	(-28°)	(-29°)	-1.9	(-12)	(-17)	(- 5.8)	(-25)	50
100	(-30)	(-15)	(-15)	+0.4	(- 6.3)	(- 8.2)	- 1.1	(-17)	100
150	(-15)	(-11)	(- 8.6)	-0.7	(- 2.4)	(- 5.6)	0.0	(- 9.6)	150
200	(- 5.5)	(- 7.0)	(- 4.8)	-1.8	- 0.3	(- 3.2)	+ 0.9	(- 5.0)	200
250	(- 1.8)	(- 3.2)	(- 2.1)	-1.5	+ 0.2	- 1.5	0.0	(- 2.4)	250
300	0.0	- 0.1	+ 0.4	+0.2	+ 1.0	+ 0.1	0.0	0.0	300
350	+ 0.2	- 0.1	+ 0.3	+0.1	+ 0.5	+ 0.4	- 0.2	0.0	350
400	+ 0.3	- 0.1	+ 1.1	+0.4	+ 0.6	+ 1.0	+ 1.2	+ 0.4	400
450	- 0.6	- 0.8	+ 0.1	+0.2	+ 0.5	+ 0.6	0.0	0.0	450
500	- 0.2	- 1.2	+ 0.8	-0.1	+ 0.8	+ 0.6	0.0	- 0.3	500
550	+ 0.2	- 0.1	+ 0.1	+1.0	+ 0.3	+ 0.5	+ 0.2	+ 0.5	550
600	- 0.6	- 0.4	- 0.5	+1.9	+ 0.1	+ 0.5	- 0.1	- 0.2	600
650	- 0.9	+ 1.4	+ 2.0	+1.5	- 0.1	+ 0.1	0.0	+ 0.3	650
700	- 0.7	0.0	0.0	+0.1	- 0.3	+ 0.1	- 0.7	+ 0.3	700
750	- 0.5	- 0.6	- 0.5	+0.1	+ 0.2	+ 0.2	+ 0.1	+ 0.5	750
800	- 0.7	- 1.0	- 1.0	-1.1	- 0.7	- 0.6	- 0.2	0.0	800
850	0.0	- 0.5	- 1.0	-0.9	- 0.1	- 0.6	- 0.6	+ 0.3	850
900	+ 1.1	- 0.2	- 0.3	-0.2	- 0.7	- 1.0	+ 0.1	+ 0.2	900
950	+ 1.7	+ 0.7	0.0	+0.8	- 1.2	- 1.0	+ 0.4	- 0.5	950
1000		+ 1.3	+ 0.1		+ 0.3	- 0.1	+ 0.4	- 0.3	1000
1050		+ 0.4	- 0.4		+ 1.5	+ 0.6	+ 1.0	- 0.1	1050
1100					+ 1.3	+ 0.4	+ 1.0	- 0.3	1100
1150					+ 1.1	+ 0.7	+ 1.6	- 0.4	1150
1200					+ 0.7	+ 0.8	+ 1.7	- 0.9	1200
1250					+ 1.1	+ 1.3		+ 0.2	1250
1300						+ 1.0		- 0.8	1300
Mean	±0.74	±0.74	±0.77	±1.02	±0.76	±0.75	±0.75	±0.40	Mean

90 Pt, 10 Pd—Pt			10 Pt, 90 Pd—Pt		Pt—Pd ₁		Pt—Pd ₂		
a	0	330	0	—596	0	0	0	0	a
10 ² × b	216·0	447·6	—211·0	—572·0	499·3	316·2	525·3	340·2	b × 10 ²
10 ⁴ × c	44·0	1·6	28·0	82·0	44·0	80·8	44·0	82·4	c × 10 ⁴
t ₁	0°	300°	0°	600°	0°	600°	0°	600°	t ₁
t ₂	300°	1200°	350°	1200°	350°	1250°	350°	1300°	t ₂
a	—	—	—	—	0·00373	0·00373	0·00377	0·00377	a
0°	0·0°		0·0°		0·0°		0·0°		0°
50	+ 2·8		0·0		— 3·1		+ 0·4		50
100	+ 1·9		— 5·8		— 0·5		— 0·2		100
150	— 1·4	(—18°)	0·0		— 1·9		— 1·1		150
200	— 2·6	(—10)	+ 4·0		+ 0·2		— 0·4		200
250	— 0·7	(— 4·1)	+18·3		+ 1·6		— 0·5		250
300	+ 3·2	— 0·6	+17·1		+ 2·1		+ 0·8		300
350	(+ 7·8)	+ 0·4	0·0		+ 0·4		— 0·2		350
400	(— 1·8)	+ 1·7		(—24°)	— 0·3	(—15°)	— 0·5	(—13°)	400
450	(—24)	+ 0·4		(—17)	(— 4·5)	(—11)	(— 4·5)	(— 8·9)	450
500	(—36)	+ 0·4		(—12)	(— 8·9)	(— 7·0)	(—10)	(— 5·8)	500
550	(—49)	+ 0·6		(— 4·8)	(—15)	(— 3·0)	(—16)	(— 2·7)	550
600		— 0·2		0·0	(—19)	— 1·6	(—27)	— 1·1	600
650		+ 0·2		0·0		+ 0·1		+ 0·1	650
700		— 0·2		0·0		+ 0·5		+ 0·9	700
750		— 0·6		0·0		+ 1·8		+ 1·5	750
800		— 0·2		—0·5		+ 0·8		+ 0·8	800
850		— 0·8		—0·2		+ 0·1		+ 1·0	850
900		0·0		—0·4		+ 0·5		+ 0·2	900
950		0·0		—0·3		+ 1·1		0·0	950
1000		— 0·4		+1·1		+ 0·9		— 0·7	1000
1050		+ 0·8		+0·6		+ 0·7		— 0·9	1050
1100		+ 0·6		—0·3		— 0·8		— 1·4	1100
1150		+ 0·6		+0·1		— 1·5		— 1·0	1150
1200		+ 0·2		+0·7		— 1·2		— 1·1	1200
1250						— 0·4		— 0·1	1250
1300								+ 0·4	1300
Mean	±2·27	±0·61	(±9·8)	±0·47	±1·61	±1·04	±0·59	±0·91	Mean

increasing purity of the metal, the gold Au_0 , according to the chemical analysis, containing 0.09 per cent iron and 0.08 per cent copper, while the two other specimens were very pure.

In order to obtain some idea of the behavior of the thermoelements below 0° , preliminary observations were made at -80° and -185° , from which it was found that all the elementary metals with the exception of palladium have a minimum in the vicinity of -100° . The difference between observed and calculated values increase as the temperature is diminished, in the case of palladium, however, the value calculated from the first equation agrees very well with the observed electromotive force at -100° .

The observed electromotive force of the several metals in microvolts at the two temperatures mentioned follows, the arrangement being the same as in the large table. For purposes of comparison the values obtained experimentally at 450° and 950° are added.

	950°	450°	-80°	-185°
Au_1	15532	5270	-307	-130
Au_2	15612	5314	-315	-166
Ag	17484	5320	-302	-160
Rh_2	12798	4422	-312	-235
Ir	11688	4146	-320	-283
90 Pt, 10 Ru ..	9814	4102	-388	-534
90 Pt, 10 Pd ..	4068	1714	-87	-106
10 Pt, 90 Pd ..	2566	-290	+146	+240
Pd_2	10670	3296	-392	-774

The platinum wire of the standard element to which all the others were referred, was further compared with another wire ($\alpha = 0.00388$) from the same source prepared with especial care. This latter, as also the wire Pd_2 , upon analysis by Prof. Mylius, showed no impurities amounting to 0.1 per cent. The electromotive force of these two platinum wires referred to the same platinum-rhodium wire showed a difference of 1° at a temperature of 1000° , while a third wire of pure platinum from another firm differed 12° at the same temperature. The last had, however, a smaller temperature coefficient ($\alpha = 0.00376$) and was in all probability less pure.

SCIENTIFIC INTELLIGENCE.

I. BOTANY.

1. *Note on Cycadofilices* ; by G. R. WIELAND (communicated).—This group of ancient plants is held to comprise the genera *Nœggerathia*, *Medullosa*, *Cladoxylon*, *Lyginodendron*, *Heterangium*, and *Protopitys*, with the Medullosan allies *Colpoxyton* and *Steloxylon*. In addition *Myeloxylon*, *Alethopteris* and *Neuropteris* are now recognized as appendicular leaf structures. Most palæobotanists regard the group as intermediate in structure between Ferns and Cycads. The literature concerning it is much enriched by the recent paper of Dr. Scott: *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks. III. On Medullosa anglica, a new representative of the Cycadofilices* ; by D. H. Scott, F.R.S. (Philosoph. Trans. of the Royal Society of London, 1899). As in the treatment of *Lyginodendron* and *Heterangium* this valuable contribution is accompanied by a full series of photographs illustrating structure. *Medullosa anglica* (from the Lower Coal Measures of Britain) is shown from the study of specimens representing all vegetative organs but the fructification to be the most Fern-like of the *Cycadofilices*. Dr. Scott's discussion of its relationships is very interesting. I quote from his conclusion: "The evidence is gradually accumulating which connects the Cycads (and by a less direct line the other gymnosperms also) with the Ferns. The fossil evidence, very strong by itself, is supported by the morphology of the reproductive organs, and by the great discovery of the multiciliate spermatozoids which we owe to Ikeno and Hirase and to Webber. We thus see that external resemblance is not always fallacious; the Fern-like foliage of *Stangeria*, the 'Maiden hair tree,' pointed in the right direction long before botanists were able to follow the clue."

2. *The Hepaticæ and Anthocerates of California* ; by MARSHALL AVERY HOWE. *Memoirs Torrey Botanical Club*, vol. vii, pp. 208, 8°, pl. 88-122. Issued Aug. 5, 1899.—This monograph is the most thorough presentation of the hepatics of any portion of the United States which has yet been published. The main portion embraces a detailed account of the genera and species found in California, with full and exact descriptions of the species supplemented by copious, critical notes on synonymy, distribution, etc., together with keys to the genera and species. In the introduction the author enumerates the different collectors of hepatics of the west coast with notes on their collections, and gives tables showing the comparative distribution of Californian species in the northeastern United States, British Isles, northern and central Europe and northern Asia. The Californian species number 86 as compared with 150 of the Eastern States, a relatively large number when one considers the smaller area covered

by the present treatise and the fact that some portions of California, especially the higher mountains, have not yet been thoroughly explored. While, on the one hand, the small rainfall of the lower districts is unfavorable to the development of a rich bryophytic vegetation, the greater height of the mountains as compared with those of the Eastern States is favorable to such development. Two facts are brought out by the table, viz., the number of species peculiar to the Pacific is proportionally greater than of those peculiar to the region of Gray's Manual, and the hepatic flora of California has more in common with Europe than with the eastern and central United States. The author has not only brought together what was previously known as to the structure and nomenclature of California hepatics, but he has also contributed a large amount of original observations in his descriptions and the accompanying notes, and the large number of illustrations add greatly to the value of this excellent monograph.

W. G. F.

3. *Californian Hypogæous Fungi*; by H. W. HARKNESS. Proc. California Acad. Sci., 3d Series, vol. i, No. 8, pp. 241-292, pl. xlii-xlv. Issued July 8, 1899. — Our knowledge of the hypogæous fungi of the United States has hitherto been very imperfect. Beyond occasional references in mycological writings and in the special papers by W. R. Gerard, we are indebted mainly to the previous papers of Dr. Harkness for what we know about our native species. The present monograph is the first extended treatise on the subject and is destined to become a classic in North American mycology. We are now able for the first time to recognize that, contrary to the general opinion, the hypogæous forms are represented by a large number of species in this country. The detection of hypogæous fungi is very difficult because in nearly all cases they exhibit above ground no evidence of their existence. Long experience and great patience are necessary to discover them and the collections of Dr. Harkness represent the labor of many years. The district examined specially by him extended from the northern State line of California to the Tehachappi range on the south and from the valley of Donner Lake on the east to the Pacific coast. The best locality for most species was found to be the foot hills at an elevation of about 1500 feet and the most productive season was early spring. Rodents it appears are very fond of the mature fungi, and they are especially destructive to forms which grow under Sequoias.

The number of species described is 105 besides three species, *Sphaeria Setchellii* Harkness, *S. Zobelii* Tul., and *Sporophuga cyanea*, the type of a new genus, which are parasitic on different Tubercaceæ. Of the 25 genera included in this monograph Leucophleps, Myrmecocystis, Piersonia and Terfeziopsis are new to science. The new species number 56, of which 8 belong to the genus Tuber, 7 to Hymenogaster and 5 to Octaviania and Leucophleps. For a detailed account the reader must be referred to descriptions and notes of Dr. Harkness given in his monograph,

which is illustrated by four folded plates, of which the drawings, in part colored, were made by Dr. Eisen. With regard to the economic value of the Californian *Hypogæa* Dr. Harkness states that he has found none of the edible varieties of Europe, although *Tuber Californica* is nearly identical with an edible species of Italy. All of the Californian species are edible, but they are so rare that their use is practically out of the question. Notes are however given concerning a species found at Marysville, belonging probably to the genus *Terfezia*, which grows in large quantities and is esteemed a delicacy.

W. G. F.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—

The forty-eighth meeting of the American Association was held at Columbus, Ohio, during the week from August 19th to 26th. The President of the meeting was President Edward Orton of Columbus. The number of members in attendance was not conspicuously large—the total registration being three hundred and fifty-two—but much interest was manifested throughout and the meeting proved as a whole highly successful; the various local committees did all in their power to contribute to this end.

The retiring President, Professor F. W. Putnam, delivered an address on Monday, August 21, upon the subject "A Problem in American Anthropology." Other able addresses were also given by the Vice Presidents of the several sections.* Another feature of the meeting was a public lecture with lantern illustrations by Professor C. E. Munroe on the application of modern explosions. Wednesday, August 23d, was devoted by the botanists to the honor of the famous bryologists, William S. Sullivan and Leo Lesquereux, both of whom had their homes in Columbus. A number of excursions were carried out, one of the most interesting being to the Gas Fields.

The place selected for the meeting of 1900 is New York City and the date set is the last week in June, a radical change which will meet with universal approval. The meeting of 1901 will be held in Denver, Colorado.

The officers nominated for 1900 are as follows :

President : R. S. Woodward, Columbia University.

Vice Presidents : Section A, Asaph Hall, Jr., University of Michigan ; Section B, Ernest Merritt, Cornell University ; Section C, James Lewis Howe, Washington and Lee University ; Section D, J. A. Brashear of Pittsburg ; Section E, J. F. Kemp, Columbia University ; Section F, C. B. Davenport, Harvard University ; Section G, W. Trelease, Missouri Botanical Garden ; Section H, A. W. Butler of Indianapolis ; Section I, C. M. Woodward of Washington University.

Permanent Secretary, L. O. Howard of Washington. General Secretary, Charles Baskerville, University of North Carolina. Treasurer, R. S. Woodward, Columbia University.

* These are printed in full in the issues of Science, commencing with August 25.

The following is a list of papers accepted for reading at the recent meeting :

SECTION A. *Mathematics and Astronomy.*

- G. B. HALSTED: Report on progress in non-Euclidean Geometry.
 L. E. DICKSON: Report on progress in the theory of linear groups.
 CLEVELAND ABBE: Recent progress in theoretical Meteorology.
 ASAPH HALL, JR.: The aberration constant from observations of Polaris.
 R. W. MCFARLAND: Ancient eclipses and chronology.
 H. C. LORD: Some points in the design of a spectroscope.
 JOS. V. COLLINS: Note on Grassmann's proof that there can be but two kinds of lineal multiplication of two factors.
 G. J. STOKES: The theory of mathematical inference.
 J. R. EASTMAN: Recent progress in positional Astronomy.
 R. A. FESSENDEN: The determination of the nature of Electricity and Magnetism, including a determination of the density of the ether.
 G. A. MILLER: On the commutators of a group.
 S. KIMURA: Linear vector functions.
 J. WOODBRIDGE DAVIS: Internal forces that generate stellar atmospheres.
 T. H. SAFFORD: Practical astronomy during the first half of the present century.

SECTION B. *Physics.*

- F. C. CALDWELL: Apparatus for the demonstration of the varying currents in the different conductors of a rotary converter.
 H. T. EDDY: A new graphical method of constructing the entropy-temperature diagram from the indicator card of a gas or an oil engine.
 WILLIAM HALLOCK: Compound harmonic vibration of a string.
 LYMAN J. BRIGGS: A new form of electrical condenser having a capacity capable of continuous adjustment.
 J. MCK. CATTELL: Time of perception as a measure of the intensity of light. Relations of time and space in vision.
 CHARLES K. WEAD: The musical scales of the Arabs. Medieval organ pipes and their bearing on the history of the scale.
 H. S. CARHART and K. E. GUTHE: An absolute determination of the E. M. F. of a Clark cell.
 AUGUSTUS TROWBRIDGE: Quantitative investigation of the coherer.
 K. E. GUTHE and M. D. ATKINS: Polarization and polarization-capacity.
 R. A. FESSENDEN: Current and voltage curves in the magnetically blown arc and in the aluminum electrolytic cell. - Some new apparatus—tachometer, chronograph, data collector, induction coil, balance for standardizing amperemeters, standard of induction. Measurement of magnetism in iron and the relation between permeability and hysteresis. Location of smokeless discharge by means of colored screens. Note on the age of the earth.
 B. E. MOORE: Polarization and internal resistance of the copper voltameter.
 C. A. SKINNER: Concerning the fall of potential at the anode in a Geissler tube.
 F. A. WOLFF, JR.: The equipment and facilities of the Office of U. S. Standard Weights and Measures for the verification of electrical standard and measuring apparatus. An experimental test of the accuracy of Ohm's law.
 O. L. FASSIG: March Weather in the United States, etc.
 D. B. BRACE: A new spectrophotometer and a method of optically calibrating the slit. On achromatic polarization in crystalline combinations.
 E. V. CAPPS: Optical calibration of the slit of a spectrometer.
 E. J. RENDTORFF: On differential dispersion in double refracting media.
 FRED E. KESTER: A method for the study of phosphorescent sulphides.
 B. V. HILL: Accidental double refraction in colloids and crystalloids.
 C. E. MENDENHALL: A bolometric study of the radiation of a black body between 600° and 1100° C.

F. A. SAUNDERS: A bolometric study of the radiation of an absolute black body.

F. E. NIPHER: On thermodynamic surfaces of P. V. T. for solid, liquid and gaseous state.

S. R. COOK: On the escape of gases from the planets according to the Kinetic Theory. On flutings in Kundt's tube.

J. S. STEVENS: Relation of magnetisation to the modulus of elasticity.

THOS. GRAY: The dielectric strength of oils. Some unexpected errors in watt-meter measurements.

DAVID P. TODD: Note on the preparation of reticles.

E. W. SCRIPTURE: The nature of spoken vowels, with reference to the theories of Helmholtz and Hermann. Electrical anesthesia.

J. F. MOHLER: Pressure and wave-length.

A. WILMER DUFF: The attenuation of sound and the constant of radiation of air.

SECTION C. *Chemistry.*

WILDER D. BANCROFT: The relation of physical Chemistry to technical Chemistry.

WM. MCPHERSON: On the constitution of oxy-azo-compounds.

W. R. WHITNEY: The nature of the change from violet to green in solutions of chromium salts.

J. J. KESSLER, JR.: Micro-structure of antimony-tin alloys.

LOUIS KAHLENBERG: The electrolytic deposition of metals from non-aqueous solutions.

A. A. NOYES: Some experimental illustrations of the electrolytic dissociation theory.

RUDOLF DERODE: Methods of analysis of sulphite solutions used in paper making.

C. G. HOPKINS: Improvement in the chemical composition of the corn kernel.

H. W. WILEY and W. H. KRUG: Some new products of maize stalks (with illustrative experiments).

E. F. LADD: Soil humus.

J. T. WILLARD: The relation of fertilizers to soil moistures.

THOS. CLARK: Secondary heptylamine.

WM. B. SHOLER: Propane trisulphonic acid.

H. C. BIDDLE: On the derivatives of isonitric of formhydroxamic acid, and their relation to fulminic acid.

JAS. H. STEBBINS, JR.: The Reichert figure of butter.

GEO. W. SARGENT: The determination of nickel in nickel steel. The quantitative estimation of boric acid in tourmaline.

W. A. NOYES and J. W. SHEPHERD: Camphoric acid, alpha-hydroxy-dihydro-cis-campholytic acid, and the synthesis of dimethyl-cyan-carbon-ethyl-cycle-pentanone.

M. GOMBERG: Diazo-caffeine. The preparation of the tri-phenyl-chlor-methane and tri-phenyl-carbinol.

F. J. POND: The action of sodium methylate upon the dibromides of propenyl compounds and unsaturated ketones.

C. C. HOWARD: Some secondary cyclic amines.

WM. MCPHERSON and ROBERT FISCHER: On naphthalene-azo-alpha-naphthol and its derivatives.

W. A. NOYES: Esterification experiments with hexa- and tetrahydroxylic acids.

CHARLES BASKERVILLE: On the condensation of chloral with ortho-, meta- and para-nitranilines. Note on the occurrence of chromium, titanium and vanadium in peats. On the universal distribution of titanium.

T. W. RICHARDS: The atomic weight of calcium.

M. E. HILTNER: Preliminary report on a new method for the determination of carbon dioxide.

A. H. GILL: Analysis of oils.

A. S. MITCHELL: Examination of lemon flavoring extracts.

F. W. WOLL: The composition of American and foreign dairy salt.

H. A. WEBER: Notes on testing soils for application of commercial fertilizers.

A. P. SAUNDERS: A determination of the transformation point of sodium sulphate.

F. P. DUNNINGTON: Notes on the estimation of total carbon in iron and steel.

H. M. FERNBERGER and E. F. SMITH: Electrolysis of metallic phosphate solutions.

F. J. POND, O. P. MAXWELL and G. M. NORMAN: The action of sodium methylate upon the dibromides of propenyl compounds and unsaturated ketones.

R. K. MEADE and J. C. ATKINS: On the determination of volatile combustible matter in coke and anthracite coal.

EDGAR F. SMITH: Observations upon tungsten.

W. L. HARLIN: The atomic mass of tungsten. Derivatives and atomic mass of palladium.

M. J. MOORE: Notes on the determination of sulphur in pig iron.

JOSEPH H. JAMES: An electrolytic study of benzoin and benzil.

J. K. HAYWOOD: Some boiling-point curves.

LILY G. KOLLACK: Electrolytic determinations and separations.

J. G. SHENGLE and E. F. SMITH: The precipitation of copper by zinc.

R. W. TUNNELL and E. F. SMITH: Action of hydrochloric acid gas upon sulphates, selenates, tellurates and phosphates.

C. H. CLARKE and E. F. SMITH: The electrolytic oxidation of succinic acid.

A. R. FOSTER and E. F. SMITH: The persulphates of rubidium, caesium and thallium.

C. A. BROWNE, Jr.: The chemical composition of butter fat The chemistry of rancidity in butter fat.

PAUL MURRILL: Halides and perhalides of the picolines.

SECTION D. *Mechanical Science and Engineering.*

W. T. MAGRUDER: Supports of beams in tests of transverse strength. Crystallization in bronze test pieces. The fracture of spheres.

THOMAS GRAY: The illustration of critical speeds of shafts. The friction of balls in thrust bearings. The fuel value of cereals.

F. C. WAGNER: A novel method of testing a locomotive boiler.

WM. S. ALDRICH: Electric mining of bituminous coal. Some engineering experiences with Spanish wrecks.

W. K. PALMER: A new exact graphical method for designing cone pulleys.

J. W. SHEPHERD: Some experiments on combustion in locomotive boilers.

C. B. MORRISON: Some thermal determinations in heating and ventilating buildings.

A. G. FRIED: Defective vision of school children.

SECTION E. *Geology.**

EDWARD ORTON: The geology of Columbus and vicinity.

FRANK LEVERETT: Glacial phenomena of Central Ohio.

WARREN UPHAM: Glacial and modified drift in Minneapolis, Minn.

G. FREDERICK WRIGHT: Lateral erosion at the mouth of Niagara Gorge.

C. H. HITCHCOCK: The geology of Oahu, Hawaiian Islands.

C. D. WALCOTT: A Pre-Cambrian Upper Algonkian terrane.

W. H. HOBBS and C. K. LEITH: The petrographic province of Fox River Valley, Wisconsin.

A. F. FOERSTE: Age and development of the Cincinnati anticline.

CHARLES SCHUCHERT: The Lower Devonian aspect of the Lower Helderberg and Oriskany formations.

H. S. WILLIAMS: The Silurian-Devonian boundary in North America.

J. J. STEVENSON: The section at Schoharie, N. Y.

JOSEPH LE CONTE: The Ozarkian and its significance in theoretic Geology.

GEORGE H. ASHLEY: The geological results of the Indiana Coal Survey.

J. A. HOLMES: The Cape Fear section in the coastal plain.

* Including papers presented before the Geological Society of America.

- E. T. DUMBLE: Triassic coal and coke of Sonora, Mexico.
 J. H. PRATT: The occurrences of corundum.
 J. A. HOLMES: Some geological conditions favoring water-power developments in the South Atlantic region.
 JOHN M. CLARKE: *Paropsonema*; a peculiar Echinoderm from the Intumescens Fauna, New York. Remarkable occurrence of Orthoceros in the Oneonta Sandstones of New York. The Squaw Island "Water Biscuit," Canandaigua Lake, New York.
 MARY A. FLEMING: The pot holes of Foster's Flats (now called Niagara Glen) on the Niagara River.
 W. SIMONDS: A consideration of the interpretation of unusual events in geological records.
 W. J. MCGEE: The Pre-Lafayette (Tennessean) base level.
 CHAS. E. SLOCUM: The relative ages of the Maumee glacial lake and the Niagara Gorge.
 F. B. TAYLOR: The Galt moraine and associated drainage.
 E. H. BARBOUR and W. C. KNIGHT: Discovery of new invertebrates in the Dinosaur beds of Wyoming.
 E. H. BARBOUR: The rapid decline of geyser activity.

SECTION F. Zoology.

- C. C. NUTTING: On the utility of phosphorescence in deep sea animals.
 B. B. MYERS: The course of the fibres in the optic chiasma of the common American toad, *Bufo lentiginosus*.
 HENRY B. WARD: On *Reighardia*, a new genus of Linguatulida.
 CARL H. EIGENMANN: Cave animals: their character, origin, and their evidence for or against the transmission of acquired characters.
 F. M. WEBSTER: Have we more than a single species of *Blissus* in North America?
 M. BURTON WILLIAMSON: Aestivation of *Epiphragmophora traskii* (Newcomb) in S. California.
 R. W. SCHUFELDT: Natural taxonomy of the class Aves.
 SUSANNA P. GAGE: Notes on the morphology of the chick's brain.
 SIMON H. GAGE: Further Notes on the Brook Lamprey (*Lampetra wilderi*). Respiration in tadpoles of the toad (*Bufo lentiginosus*). Photographing Natural History specimens under water or other liquids with a vertical camera.
 H. C. OBERHOLSE: Geographical variations illustrated by the horned larks of North America.
 W. G. JOHNSON: Effects of hydrocyanic acid gas upon animal life and its common use.
 C. L. MARLATT: A discussion of *Aspidiotus cydoniae* and its allies.
 B. F. KINGSBURY: The histogenesis of muscle in the metamorphosis of the toad. (*Bufo lentig. Americanus*)
 THEO. GILL: The progenitors of Batrachians.
 HERBERT OSBORN: Observations on the variation, life-history and habits of a minute locust (*Edipoda maritima* Uhl (?)).
 A. D. HOPKINS: A chart for illustrating the origin and evolution of animal and vegetable life.

SECTION G. Botany.*

- F. L. STEVENS: The fertilization of *Albugo bliti*.
 FRANCIS RAMALEY: The embryo sac of *Leucocrinum montanum*.
 A. S. HITCHCOCK: Notes on subterranean organs.
 W. J. BEAL: Some monstrosities in spikelets of *Eragrostis* and *Setaria* with their meaning.
 C. E. BESSEY: Studies of vegetation of the high Nebraska plains. One thousand miles for a fern. Are the trees advancing or retreating upon the Nebraska plains?

* Including also (below) titles of papers presented before the Botanical Club.

WM. SAUNDERS: The breeding of apples for the Northwest plains. Useful trees and shrubs for the Northwest plains of Canada.

BYRON D. HALSTED: Field experiments with "Nitragin" and other germ fertilizers.

A. J. GROUT: Suggestions for a more satisfactory classification of the Pleurocarpous mosses.

BRUCE FINK: Notes concerning the study of lichen distribution in the Mississippi Valley.

W. C. STEVENS: Botanical teaching in the secondary schools.

IDA CLENDENIN: Botanical teaching in the secondary schools.

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OBITUARY.

Professor ROBERT WILHELM BUNSEN, the veteran German chemist, died in Heidelberg on the 16th of August last at the age of eighty-eight. Of what he accomplished for science during his long period of active service, only brought to a close by the infirmities of great age, chemists and physicists hardly need to be informed—with the founding of the department of spectrum analysis and the development of the methods of gas analysis, his name will be ever as surely connected as it is in popular use with the “Bunsen burner.” But to those who enjoyed the privilege of working under him, of learning to know personally as well as to come into somewhat close contact with his keen mind, his death comes as a direct personal loss. This is so well expressed by a gifted chemist* in a recent number of *Nature* that no apology is needed for quoting his words here: . . . “But this experimental work, great and important as it is, is not the greatest or most important work that he accomplished. It is as a teacher and as an example that the name of Bunsen is and will be chiefly honored and remembered. It is only those who have had the benefit of working under and with him who can fully understand the feelings of affection and respect with which they regard his memory. To those who had the privilege of his intimacy, of whom I can happily claim to be one, his friendship will remain as an abiding source of gratification. As an investigator he was great, as a teacher he was greater, as a man and a friend he was greatest.”

SIR EDWARD FRANKLAND, the distinguished English chemist, died on the 9th of August in his seventy-fifth year. A recent writer says of him, his “title to fame rests securely upon his important experimental investigations in pure chemistry, accomplished chiefly within the twenty years from 1848 to 1868, and upon the impetus which was given to theoretical chemistry by the promulgation of his views concerning the combining capacity, or valency as it is now called, of the elements, which he derived from the results of his experimental work.”

DR. DANIEL GARRISON BRINTON of Philadelphia, the distinguished and learned anthropologist, died on July 31st in his sixty-third year. He held for many years the Professorship of American Archaeology and Linguistics in the University of Pennsylvania. His contributions to science, particularly in the line of the languages of the original tribes of North America, were numerous and of great value.

*Sir Henry E. Roscoe in *Nature* for August 31. The same writer gave an admirable account of Bunsen's life and work some eighteen years since in vol. xxiii of *Nature's Series of Science Worthies*.

WONDERFUL QUARTZ TWINS.



The announcement in our last Winter Bulletin of our purchase of the *finest and largest contact twins of Quartz which ever left Japan*, may now be supplemented by the announcement in our Fall Bulletin, just published, of the addition on Sept. 7th of forty twins, and the presentation of a photograph of thirty-five of them. None of this new lot are equal to the best of those secured last winter, all of which were quickly sold out at prices ranging from \$30 to \$82.62, but there are a number of most excellent twins averaging 2 to 3 inches in diameter, and a few still larger ones. While all of them are more or less bruised, the average of reasonably perfect specimens is larger than in last winter's lot. These large twins are *not a new find*, their discovery having been made some twenty years ago; our latest accessions are the result of most diligent search throughout the region, and are not likely ever again to be duplicated. Prices, \$2 to \$20.

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T H E

AMERICAN JOURNAL OF SCIENCE

[F O U R T H S E R I E S .]

ART. XL.—*Types of March Weather in the United States. The relations existing between mean atmospheric pressure, the prevailing character of the weather, and the paths of storms*; by OLIVER LANARD FASSIG. With Plates VI and VII.

Introduction.—It has long been recognized that the field of view of a national weather service is too small to study to the best advantage the daily weather phenomena as they pass over any one country.

In the past twenty years, several researches of great importance have appeared in which the field of investigation comprised large portions of the northern hemisphere, some of them indeed including both hemispheres. The results of these investigations show that the weather of a certain locality is intimately associated with atmospheric conditions very far removed from the immediate locality under consideration. For example, Hoffmeyer and Teisserenc de Bort have shown that certain conditions of pressure over the North Atlantic Ocean have a direct bearing upon the weather of Central Europe. Blandford and Eliot have demonstrated that certain marked phases of Indian weather find their explanation in pressure conditions in Central Asia and over the Indian Ocean. There are a few well-defined and persistent areas of high and low pressure of great extent in both hemispheres which control very largely the weather conditions of the globe. Recent researches tend to show that some of the attention heretofore given to transient cyclonic areas might well be diverted to the study of the so-called *permanent* high areas. The extensive areas of high pressure found upon any chart showing the mean monthly pressure conditions over the globe are real forces in

controlling the weather over wide areas. Any marked displacement of these areas from their normal or average position, or any unusual variation in the intensity of their gradients, is associated with unusual conditions of wind direction, temperature, and rainfall in their vicinity. The daily weather chart has made us all familiar with the kind of weather associated with the transient areas of high and low pressure which pass across the country every few days: with the clear skies and light, variable winds of a high area, the rainy unsettled weather near the center of low pressure. In interpreting the average weather conditions associated with the large persistent areas of average high or low pressure we find that the same rules apply as in the case of the transient areas based on synchronous observations.

In view of the slow movements of these areas of high and low pressure, their vastly greater extent and greater persistence, we have, for purposes of weather forecasting, an evident advantage over the method of following up the quickly moving cyclones and anti-cyclones of smaller extent, which may enable us to foresee the general character of the weather, for longer periods than we are now able to do.

A better knowledge of the movements of these "great centers of action," as M. Teisserenc de Bort calls them, would undoubtedly prove a valuable supplement to present methods in the practical work of forecasting. For example, should further investigation show that, when the pressure in the North Atlantic high area is above its normal value, and extends farther inland than usual, the paths of all storms, including the West Indian hurricanes which may arise during this time, are moved westward of their usual paths, we shall be able to determine much more accurately the probable paths of our storms.

In any event, since no material improvement has been made in late years in either the accuracy or the period of weather forecasts, it behooves us to give every encouragement to any suggestion which gives reasonable promise of advance, especially in the direction of forecasts for a longer period.

In the following pages a brief synopsis of the more important researches referred to above is presented in order to give a clearer conception of their nature and claims. I have attempted to follow a similar method of investigation in a detailed study of March weather conditions in the United States, with special reference to the Middle Atlantic States. An effort is here made to show that the weather east of the Rocky Mountains is largely controlled during March in its general characteristics by the relative development and the relative positions of the persistent areas of high pressure over the Atlantic Ocean and over Manitoba in British North

America. The study of conditions during March brings to light several interesting facts about the controlling factors in the weather east of the Rocky Mountains. An average pressure above the normal in the area of persistent high pressure over the Atlantic Ocean invariably brings to the Atlantic States mild ocean temperatures; an average pressure above the normal of the persistent high area over the interior of British North America as invariably brings to the Central and Atlantic States the cold air of the northwest. During a normal month of March the Atlantic States are alternately under the control of the high area in the northwest and that over the Atlantic Ocean, resulting in the changeable weather and strong contrasts in temperature so characteristic of March.

An intimate relation is also shown to exist between these pressure areas and the distribution and amount of rainfall, and in the paths of storms across the country.

Historical review.—Hoffmeyer, the eminent Director of the Danish Meteorological Service, as early as 1878 recognized the importance of securing observations over the widest field possible in the discussion of weather sequences.* It is to his efforts that the world is indebted for initiating in 1873 the excellent series of daily synoptic weather charts of the North Atlantic Ocean and Western Europe. He showed to what a great extent the winter conditions of Northern Europe are dependent upon the prevailing pressure distribution over the North Atlantic Ocean. He made a careful study of the origins and paths of storms over the Atlantic Ocean,† and pointed out how it would be practicable by joining Iceland, Greenland, the Azores and Bermuda, with neighboring mainlands by cable, to secure a daily weather chart sufficiently comprehensive to permit of making fairly accurate forecasts of the approach of storms, and to note carefully the pressure changes in the area of persistent high pressure in the neighborhood of the Azores.

The winter of 1879–80 was very severe throughout Central Europe; M. Léon Teisserenc de Bort,‡ of the Central Meteorological Bureau of France, made a careful study of the conditions which prevailed, and of the causes which produced them. In charting the mean monthly pressure over the North Atlantic and over Europe for the months of December, January and February, it was revealed that during December

* Distribution de la pression atmosphérique pendant l'hiver sur l'Océan Atlantique Septentrional et influence que en résulte sur le climat de Europe. In Cong. intern. mét., Paris, 1878; also in *Met. Zeitschr.*, Wien, 1878, pp. 337–347, 5 pls.

† Étude sur les tempêtes de l'Atlantique Septentrional. 4°. Copenhagen, 1880. 47 pp. 4 pls.; also in *Met. Zeitschr.*, Wien, 1880, pp. 345–361.

‡ Étude sur l'hiver de 1879–80. *Annal. du Bureau Centr. Mét.*, Paris, vol. iv, 1881.

the area of high pressure, usually over the Azores, throughout the year, was during this month over France and neighboring regions; during a portion of January the area had resumed its normal position; again during February it was found over France. The normal distribution of pressure during the winter months gives to France a mild climate with prevailing southwesterly winds. During the presence over France of the area of high pressure, however, in December and February some of the lowest temperatures experienced during the present century occurred; the prevailing winds were northerly and much of the precipitation was in the form of snow and not in the usual form of rain. Further study of mean pressure conditions over the globe for a long series of years led M. Teisserenc de Bort to define and classify the different maximum and minimum areas of pressure which the atmosphere presents at the surface of the earth. These areas, which have a certain permanence in a given season and which are found on all charts of mean pressure, he designates "great centers of action of the atmosphere." Their existence is related to the position of the great centers of action of the globe, regions which either by their physical properties or by their orographic features initiate the great centers of atmospheric action, so-called because they govern the circulation of the winds all round them. These centers of action vary considerably from year to year, during the same month, in position and in extent. Their motion is not a regularly progressive movement in the well-defined direction made familiar to us in the study of the transient highs and lows of our daily weather map, but is irregular, a shifting from place to place—now to the north or south, then to the east or west, of an average position—following no law at present recognizable. It was shown that the character of a season is well defined when it is known what types of isobars prevail. Two important principles have been formulated by M. Teisserenc de Bort as a result of these studies:

1. When a region of a certain extent shows an excess of temperature either absolute or relative to the temperature of other points in the same latitude, there is a tendency to the formation of a minimum in that region, and an almost exact coincidence between the barometric minimum and the maximum of temperature; moreover there is a certain proportionality between them. This tendency is shown either by the existence of a closed minimum, or by an inflection of the isobars.

2. Areas of maximum pressure have a tendency to form in the neighborhood of regions where the temperature is low, either absolutely or relatively to their latitude.

The general circulation of the atmosphere due simply to difference in temperature between the equator and the poles, would produce a belt of high pressure around the globe near latitude 30° N. The differences of temperature which are produced over the globe between neighboring regions, and especially between continents and seas in the same latitude, by changing the density of the lower strata of the atmosphere, destroy the regularity of the isobars (as observed in the southern hemisphere) and bring about the formation of closed areas of high or low pressure which break up the zones, as shown in the northern hemisphere. (See Plate VI.)

In these researches of M. Teisserenc de Bort we have the first indications of a method which may lead to long-range forecasts. Van Bebber* suggests that the barometric maxima owe their origin and life mostly to the upper air currents; so that the air masses which are carried up in certain regions, even in the high latitudes and in the lower atmosphere, go to build up the highs. The usual explanation, he maintains, that the barometric maxima are fed by passing depressions, does not suffice, and leads to many contradictions.

General Greeley maintains† that “a study of the annual barometric fluctuations will reveal their intimate connection with the prevalent types of weather or climate, so that abnormal departures in certain regions will be recognized as dominating factors in producing, later in the season, abnormal weather conditions in other and quite distant sections of the world.” That “annual atmospheric waves, with their crests and troughs, move over the northern hemisphere somewhat in the same manner as the waves of high pressure, known as cold waves, move throughout the winter months from the interior to the Atlantic seaboard.”

Mr. Eliot,‡ the Meteorological Reporter to the Government of India, seems to have established:

1. That there are well-marked pressure oscillations of long period over the Indian area.
2. That they are directly related to the largest and most important features of the weather in India, viz: the character and distribution of the precipitation of rain and snow in the Indian monsoon area.
3. That they are also directly related to the great atmospheric movements over India.

* J. van Bebber, *Typische Witterungserscheinungen*. Archiv der deutschen Seewarte, v. 1882. 4^o. Hamburg, 1882.

† International pressure and storm charts. Report of Chief Signal Officer for 1891. Washington, 1891, page 750

‡ J. Eliot, A preliminary discussion of certain oscillatory changes of pressure of long period and short period in India. Indian Met'l. Mem., vol. vi, part ii, Calcutta, 1895, page 117.

Hildebrandsson* finds that the barometric variations about the Azores and about Iceland are nearly always opposed. That the same is true of the variations in Siberia and Alaska. That there exists a sort of oscillation in the pressure of the air between a center of action of high pressure and another neighboring one of low pressure. In comparing, on the other hand, the curves for the Azores and for Siberia, he finds a remarkable agreement. The variations at Key West do not accord with those in the Azores, but are in accord with those at San Diego. The departures of the same sign nearly always cover very large areas.

According to Major Rawson,† the so called permanent areas of high pressure in the northern hemisphere do not have a steady progressive movement, but shift to one side or another about a fairly well-defined average position.

Poincaré‡ has in recent years presented to the French Academy of Sciences many communications upon the probable cause of these anomalous pressure changes, attributing them to the influence of the moon.

Thus we see that there is abundant testimony to establish the existence of well-defined larger movements of the atmosphere, which differ in extent and character of movement from the transient high and low areas pictured upon our daily weather maps; also that these movements have a direct and important bearing upon local climate. Leaving the historical side of the question, we come to the consideration of the positions occupied by these persistent areas of high and low pressure during March, and their influence upon local climates in the United States.

Average weather conditions during March.—In a study of weather conditions it is essential to bear in mind the "law of winds" announced independently over fifty years ago by our own countryman William Ferrel, and by Buys-Ballot of Holland: where there is a difference of pressure between neighboring regions on the same level the air will flow out of the region of high pressure into the region of low pressure. Owing to the revolution of the earth about its axis the flow of air will not be along straight lines, but along lines constantly bending to the right of the initial direction in the northern hemisphere; to the left in the southern hemisphere. The daily weather chart issued by the United States Weather Bureau has made us familiar with such systems of wind circulation as they pass across the country every few days, and has

* Quelques recherches sur les centres d'action de l'atmosphère. Stockholm, 1897.

† Anticyclonic systems and their movements, Quart. Journ. Met. Soc., London, vol. xxiv, 1898.

‡ See Compt. Rend., Acad. Sci., Paris, 1889 et seq.

enabled us to see why the winds at any given place change rapidly in direction as an area of low or high pressure passes over the place. It is also essential to bear in mind certain relations existing between temperature and moisture conditions of the atmosphere. At a given temperature the maximum amount of invisible moisture in a given space is a fixed quantity. Should the temperature be lowered, some of the moisture will assume a visible form such as cloud or rain. Conversely, if the temperature be raised the space will become dryer as the capacity for moisture is increased by raising the temperature. Hence a portion of atmosphere rising from the surface of the earth will become relatively more moist as it rises, owing to the decrease in temperature upward from the surface. As the atmosphere contains at all times more or less moisture, a rising current will produce clouds and eventually rain, while a descending atmosphere becomes relatively dryer as it descends.

Now let us apply these simple laws to conditions in areas of low and high pressure. In a low pressure area we have seen that the atmosphere flows in toward the center from all directions, consequently at or near the center of the area it must rise and be lowered in temperature; the moisture of the atmosphere will approach saturation; clouds will be formed and if it continue to rise rain will follow. Hence an area of low pressure is apt to be characterized by cloudy and rainy weather. The atmosphere in a region of high pressure descends; hence it grows warmer as it descends. As it grows warmer, it becomes dryer; any clouds which may have existed over this area tend to become dissolved. Hence an area of high pressure is an area of clearing or clear weather. We shall see later that these principles hold good for average pressure conditions as well as for the transient conditions shown on our daily weather maps. That is to say, if in a certain region we find the mean pressure for the month to be considerably higher than in neighboring regions, the weather there will be found to be generally fair; while in a region where the pressure has been relatively low the prevailing weather will be found to be cloudy and unsettled. We can now see that if we can definitely locate areas of mean high pressure and mean low pressure, during a specified time, we shall have a means of determining readily the prevailing direction of the winds, this, in turn, enabling us to determine roughly the temperature and the rainfall.

Throughout this discussion I have considered the isobar of 30.1 inches as defining roughly the outer limit of a high area, and the isobar of 29.9 inches as enclosing the area of low pressure.

This division into high and low areas has been uniformly maintained for convenience. These limits were adopted as the mean atmospheric pressure at sea level is approximately 30.0 inches; any area above 30.1 inches is consequently safely above normal, while any area below 29.9 inches is safely below normal.

The characteristic features of pressure distribution during March in the northern hemisphere are as follows: a large area of excessively high pressure (see Plate VI) prevails over Asia. In the western hemisphere there are three well-defined areas of high pressure: one over British North America, another extending across the North Atlantic at about the latitude of thirty degrees, from the Azores westward, the third in the Pacific Ocean between California and the Hawaiian Islands. This triple arrangement of the areas of high pressure about the United States during March plays a most important part in determining the character of the weather. The areas of low pressure in the extreme northern portion of the Atlantic and Pacific Oceans are well developed and clearly defined.

March is proverbially a windy month, with strong contrasts and rapid changes in temperature. It is a transitional month, during which there is a breaking up of winter conditions and a beginning of summer conditions. The Middle Atlantic States (see Plate VI) lie between the normal March isotherms of 25° and 45°, though the mean temperature varies greatly from year to year. At Baltimore, where the normal March temperature is 42°, the values have varied from 35° to 49° during the past thirty years. The rainfall east of the Rocky Mountains attains a maximum of from five inches to seven inches in the eastern Gulf States and diminishes steadily to the west and north to about one inch over the Rocky Mountain plateau. Storms are frequent, and their paths across the country evenly distributed from the Lake region to the Gulf (see fig. 1, p. 335).

March, 1898.—See Plate VII. The month of March, 1898, was excessively warm in Maryland and Delaware; at Baltimore the daily excess of temperature was over seven degrees. There was but one short period of frost and this was free from injurious effects upon crops in these States. There were but few high winds and none of them destructive. The month was balmy and almost devoid of the usual stormy March winds. The rainfall, while somewhat below the normal, was sufficient to supply all the needs of growing crops. Crop correspondents of the United States Weather Bureau in Maryland and Delaware reported vegetation at the close of the month from three to four weeks in advance of the average season.

In looking for an explanation for the unusually warm spell of weather, it is found necessary to go far beyond the limits of these States. Reference to the Climate and Crop Report of the Weather Bureau for this month showed that the temperature was above the normal in all sections of the country east of the 100th meridian, the largest excess being in southern Canada, where it reached twelve degrees. West of the 100th meridian the temperature was everywhere below the normal, in Montana the departure being minus nine degrees. According to the United States Monthly Weather Review, the pressure was above normal from the Mississippi River eastward to the Atlantic coast, also on the northern slope and the north Pacific coast. It was below normal over California, the southwest, the Rocky Mountain regions south of Idaho and the plains from the Gulf of Mexico to the British possessions. The pressure was unusually high for the season over New England and the Canadian maritime provinces. The areas of high pressure of the month in most cases followed the northern track and persisted for several days over New England. The low areas in the majority of cases moved from the southwest to the lake region, then easterly north of New England. As a result the prevailing winds were southerly, giving fair weather and abnormally high temperatures to all of New England. The dividing line between southerly winds on the one hand, and northwesterly winds on the other extended northeasterly from Denver to Duluth, a position considerably farther to the northwest than usual. The winds of the Pacific coast were almost invariably from the northwest, while those of the mountain and plateau region were generally southwesterly. The rainfall was below the normal in the Atlantic coast and east Gulf States, and also in all the Pacific coast States; it was abundant in the Ohio and Mississippi Valleys.

In order to get a more comprehensive view of the situation, the pressure conditions prevailing over the entire continent, so far as observations could be gathered, were charted. Observations of mean atmospheric pressure were, at the same time; charted for the entire northern hemisphere so far as material was available, in order to study the situation in its broadest relations. The result is shown on Plate VII.

Looking at the pressure conditions over the North American continent and the neighboring oceans, and bearing in mind the principles referred to in the preceding paragraphs relating to wind and weather conditions in high areas and low areas of pressure, the abnormal weather conditions during March find a ready explanation.

The area of high pressure over the Atlantic which usually

extends from the Azores westward to Florida (see Plate VI) was, during March, 1898, materially modified in form and extent: it was found to be divided into two segments with the western segment unusually developed and enlarged. Over the entire eastern section of the United States and Canada the weather was under the control of a high area of exceptional strength for the season and the place, which brought to these regions either light variable winds or southerly winds. During the entire month ocean conditions prevailed, that is, the temperatures were equable in the main, and the regions were mostly free from the usual incursions of the cold continental weather conditions from the northwest. The low temperatures of the North Pacific coast find a similar explanation in the position and development of the high area in the north Pacific. The normal position of the Pacific Ocean high area brings to the North Pacific coast a mild, southwesterly wind. During March, 1898, this high area was found farther to the north and at the same time having greater energy than usual, thus bringing a colder northwesterly wind to these regions.

A glance at the chart will show that the high area over British North America was about normally developed and exerted no abnormal influence upon the temperature of the neighboring regions.

An abnormal distribution of pressure is also shown over the eastern North Atlantic and over Central Europe. Let us examine the records to see whether this departure in pressure distribution was accompanied by abnormal weather conditions in accordance with this distribution of pressure. Again examining Plate VI and bearing in mind the law of winds, we see that the prevailing winds over central and eastern Europe are from the southwest, bringing with them mild ocean temperatures and frequent rains.

During March, 1898 (see Plate VII) a segment of the Atlantic high area was found considerably to the north of its usual position, while a trough of low pressure existed over Central Europe. This distribution of pressure gives to the coast regions and to England northerly winds with low temperatures and precipitation in the form of snow. To Central Europe it brings southeasterly winds with rains, the direction of the wind being largely controlled by the excessively developed Siberian high area. Quoting from the *Weekly Weather Review* of the London Meteorological Office, we find that "with the exception of a few mild days about the middle of the month the weather of March was generally cold and changeable with frequent showers of snow or sleet. . . . Until the concluding week very few depressions of importance were observed in the immediate neighborhood of our islands,

the centers of the large Atlantic disturbances keeping as a rule well away to the northward. Winds varied considerably but were mainly from the west in Scotland and from the north or northeast in England and Ireland."

Crossing the channel into France, we find that the weather was generally cold, being 3° below the normal at Paris. The dominant winds were from the northeast with prolonged rains. Snows were more frequent than rains in the northwest and the north of Europe, according to the monthly bulletin of the French Meteorological Bureau. From "*Das Wetter*" for March, 1898, we learn that the weather of central Europe was of a kind generally associated with low areas; cloudiness was far above the average, the rainfall was generally above the normal. Temperatures varied, being above in some sections and below in others, on the whole not deviating far from the normal.

In a method similar to that just described, pressure conditions were charted for the month of March for all years from 1877 to 1899; where observations were available, isobars were drawn for the entire northern hemisphere, but the investigation of weather conditions was confined to the United States, with special reference to the Middle Atlantic States. Having drawn the isobars, the departures from normal temperature and rainfall were entered upon the same chart. The months were then classified according to the departures from the normal temperature, in order to learn what relations existed between the distribution of pressure and the temperature departures.

The mean temperature of March was found to be decidedly above the normal during the years 1878, 1882, 1894, and 1898 in the Middle Atlantic States.

Warm Marches: March, 1878.—The temperature was excessively high in all portions of the United States and Canada, with a maximum departure of $+20^{\circ}$ over Manitoba; from this center the departures gradually diminished to 4° or 5° on the Atlantic and Gulf coasts and to 3° or 4° on the Pacific coast. The striking feature about the pressure distribution was the total absence of the high area usually over British North America, at least up to 60° north latitude. In the central portion of the United States, where the pressure usually averages about 30.0 inches, it was below 29.9 inches, causing a well-developed barometric depression. This distribution of pressure caused prevailing winds to blow into the central portion of the country from the Atlantic Ocean, the Gulf, and from the Pacific Ocean. The Atlantic high area, while only normally developed in its western extension, practically controlled the wind directions and temperatures over a great extent owing to the absence of the British high. The precipi-

tation was deficient east of the Mississippi River and south of the Lakes.

March, 1882, fig. 3.—During this month the temperatures were from 2° to 4° above normal in nearly all sections east of the Mississippi River; to the west and northwest they were from 4° to 8° above. The pressure distribution was totally different from that of March, 1878, but the eastern half of the country was again plainly under the influence of the Atlantic high area; this was not only unusually strong but extended inland far beyond the average limits. All the characteristics of high area weather prevailed in the eastern and southern states during the month; high temperatures, light winds, and comparatively dry weather. The northern high area was well developed but the center was farther to the north and east than usual, and not in a position to throw detached masses of cold air into the United States. Without observations to fix the position of the Pacific high, it is difficult to discuss intelligently the control of weather on the Pacific coast.

March, 1894.—The temperatures ranged from normal along the 105° meridian to 9° above in the Lake regions and to 3° below westward to the Pacific coast, again showing a decided control of the country east of the Mississippi by the Atlantic high area. The rainfall was deficient almost throughout the area enclosed by the isobar of 30.1 inches.

It is clearly apparent from a study of the foregoing analysis that in each case the eastern half of the country was under the domination of an extension of the Atlantic area of high pressure, which gave to this region either prevailing southerly or easterly winds from a warmer region, or prevailing light, variable winds. It will also be noted that when a region is clearly within this high area, generally within the isobar of 30.1 inches, there is a deficiency of rain, even when easterly winds are indicated by the arrangement of the isobars.

We see that the Middle Atlantic States and neighboring regions may be warmed owing to an unusual extension westward, or increased intensity of the Atlantic high area, as in 1882, 1894, and 1898; or it may be owing to the retreat northward of the British American high area, as in 1878. In either case there is a comparative absence of the cold northwesterly winds which are a characteristic feature of the normal March, in which there is more or less of a see-saw between the domination of winds from the northwest and those from the southeast. All warm Marches fall into one or the other of these two classes.

Cold Marches.—We come now to the consideration of another class of March conditions, those having mean tem-

peratures decidedly below the normal in the Middle Atlantic States.

March, 1883, Plate VII.—An examination of the chart will show a large area, everywhere east of the 105th meridian, in which the temperatures were below the average. The departures were not large but were uniformly below the normal east of this meridian, and as uniformly above normal from this meridian to the Pacific coast. The striking feature of the pressure distribution was the strength of the continental high area, together with the lack of development of the Atlantic high area in the western portion of the ocean. Such a system brings prevailing northerly or northwesterly winds to all sections in the eastern half of the country. The mild weather resulting from high pressure over the western Atlantic Ocean was absent. The cold and dry northwesterly winds meet with comparatively little opposition in their passage across the country, such as they meet with when the Atlantic high is well marked; there is a deficiency of rainfall, as is distinctly shown by the figures.

March, 1885, fig. 4.—In March, 1885, the line of temperature departure was again in the region of the 100th meridian, with decided minus departures eastward to the Atlantic Ocean and plus departures westward to the Pacific Ocean. The continental high area covers the entire country, with its greatest development over the northern plateau region, considerably to the south of its usual position. Here again the Atlantic high falls short of extending its influence to our coasts; while well developed it is found farther eastward with its axis inclined from southwest to northeast. The continental high again plainly dominates the weather of the United States. The fact that the center of the continental high area is so much farther to the south of its usual position is sufficient explanation to account for the temperatures above normal west of the 100th meridian. With this position of the center the bodily transfer of cold air from the neighborhood of Hudson's Bay does not take place, and hence there would not be the usual frequency of cold northerly winds.

March, 1888.—During this month temperatures were below normal throughout the United States and the Canadian provinces. In Manitoba the departure was minus ten degrees. From this point the departures diminished in all directions to the east, south, and west. In the Middle Atlantic States they were from 3° to 4° below; on the Pacific coast, temperatures were nearly normal. An area of high pressure of unusual intensity covered the greater part of British North America, the pressure over a large portion of this area reaching 30.3 inches. Over the Atlantic Ocean the high area is normally developed

both as to its form and intensity, but is found fully ten degrees farther south than its usual position. These two high areas are joined over the United States, giving the Atlantic Ocean high area the appearance of a prolongation of the continental high area; the latter, however, both on account of its great extent, and its steep gradient, clearly controls the situation, throughout the continent. The rainfall was nearly normal in all sections of the country, excepting in the western Gulf States, where there was an excess of about two inches. The permanent low area in the North Atlantic is found fully 20° south of its normal position. Central Europe is found in the center of this depression with all the characteristics of "depression weather."

March, 1891.—In this month we find the average temperatures again below the normal in all portions of the United States. The departures are nearly normal along the Atlantic and Pacific coasts and increase towards the 100th meridian, along which the departures reach minus eight degrees to minus ten degrees. The continental high area extends considerably beyond its normal eastern limit, with approximately normal intensity. Observations were not available to fix the position of the Atlantic high area, but at least its western extremity was but slightly developed, as there is no evidence of it in the pressure observations of the South Atlantic States. The rainfall of the month was nearly normal, excepting in the Middle Atlantic States, the Ohio Valley, and the East Gulf States, where it was considerably in excess of the normal, and upon the Pacific coast, where it was somewhat below.

March, 1897, cold in the extreme northwest, fig. 2.—The temperatures are from 3° to 6° above normal in all sections east of a line running from Duluth to Amarillo, Texas; to the west of this line, the temperatures are all below normal with a maximum departure of minus twenty degrees north of Montana. So far as the eastern States are concerned this belongs to the warm type of March; as, however, the greater part of the country is below normal, and the temperatures in the northwest are phenomenally low, it is described with the cold types. Here we have both the continental high and the Atlantic high with a nearly normal development in intensity but extending somewhat beyond their usual limits. In strength they are apparently equal, the Atlantic high controlling the eastern half of the country and the continental high the western half. On the Pacific coast we find the high area with apparently a normal development but somewhat to the south of its usual position. In the neighborhood of Puget Sound there is a low area. This distribution of pressure on the Pacific coast, together with a fair development of the conti-

mental high area appears to be particularly favorable for the production of low temperatures in the extreme northwest, the low pressure near Puget Sound facilitating the transfer of cold air from the interior toward the coast. The rainfall was considerably above normal in the Mississippi and the Ohio Valleys and somewhat above on the Pacific coast; it was below normal on the Atlantic coast within the area enclosed by the isobar of 30.1 inches.

March, 1899, cold in extreme northwest.—The conditions were somewhat similar to those of March, 1897. The temperatures were slightly above normal east of a line running from Boston southwest to Amarillo, Texas; to the west and north of this line, temperatures were everywhere below the normal, the greatest departures being in Montana, where they reached the excessive value of minus twenty degrees. The continental high was strongly developed. Its influence was felt in nearly all sections of the country reaching eastward as far as the lower Lake region and southward to Texas, the normal development of the Atlantic high area checking the further extension of its influence eastward. The rainfall was excessive in the Ohio Valley and Tennessee, in New England and in California; it was deficient in the South Atlantic and Gulf States, and in the neighborhood of Puget Sound.

The months cited above include all those during which there was a marked mean temperature below the normal east of the Mississippi River from 1876 to 1899, and two of extreme departures in the northwest. A characteristic feature of the former is a marked development of the continental high area, or a weak development or absence of the Atlantic high area in the region of the South Atlantic States. Again we notice a deficiency in rainfall in nearly all cases in which the region is clearly within the high pressure area, though this is not so universally true as in the case of the Atlantic high. All these conditions of pressure distribution naturally produce winds prevailing from a northerly or a westerly direction, which bring with them the severe temperatures of the interior of the continent.

Extent and Intensity of Cold and Warm Periods.—The geographical extent and the amount of departure from the normal temperature are indicated upon the charts. By charting the mean pressure distribution in connection with the lines of equal temperature departure, we see readily why one section of the country may enjoy mild weather while in a neighboring section the weather may be exceptionally severe. We see also that the entire country may at the same time have temperatures considerably above or below normal.

The relation between pressure and rainfall.—Some interest-

ing relations between rainfall and mean pressure conditions have come to light in this investigation. The decidedly cold, as well as the decidedly warm months, were deficient in rainfall. In each case, in the Middle Atlantic States, "high area" weather prevailed, the region being either well within the Canadian high area or well within the Atlantic high area.

The extent and persistence of these areas of high pressure over any region define the geographic limits and the duration of a drought. Should we be enabled, by further study of the problem, to learn the law of movement of these high areas, it will become a comparatively easy problem to forecast periods of drought and of abundant rains in the United States. A similar method is already practiced in India, with a fair measure of success, in forecasting the monsoon and the winter rains.

During months having a rainfall above the normal in the Middle Atlantic States, this region was almost always within a trough of average low pressure, or near the western or northern edge of the Atlantic high area.

Average pressure distribution and the paths of storms.—Some interesting and suggestive points are brought out by charting storm tracks in connection with the mean pressure distribution during the month, and comparing the results with the normal distribution of pressure and storm paths.*

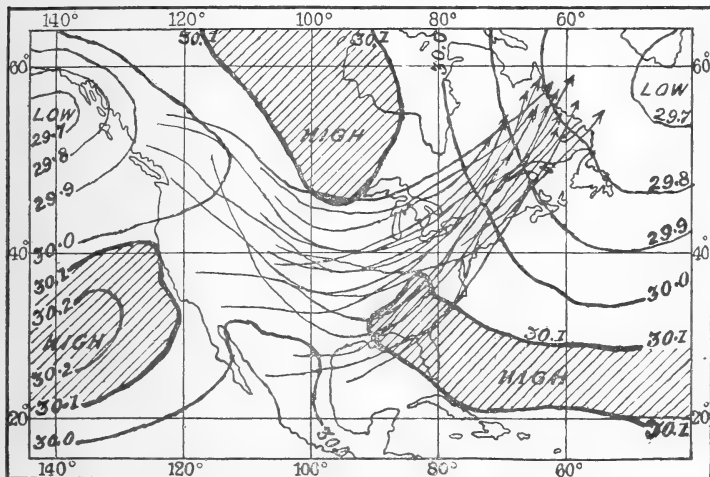
Fig. 1 shows the normal storm tracks during March. As has already been pointed out, during March the continental high and the Atlantic high areas are, within the limits of the United States, quite equally balanced in strength. It will be observed that the storm paths while normal pressure conditions exist, are spread quite uniformly over the country from the Great Lakes to the Gulf, and converge in the neighborhood of Labrador on leaving the United States. I have plotted the storm paths of March in connection with the pressure distribution during several characteristic abnormal departures of pressure. In fig. 2 for March, 1897, they are found in a narrow band extending east and west across the Lakes and down the St. Lawrence Valley. Fig. 3 for March, 1882, shows a crowding together of the storm paths into a comparatively narrow band, extending from northeast to southwest, across the Lake Region and down the St. Lawrence Valley. In fig. 4 for March, 1885, the paths are mostly north of their usual position, with some along the Atlantic coast, while the central portion of the country is comparatively free from storm paths.

Mean pressure distribution and the paths of West Indian hurricanes.—In order to learn whether the path of a West Indian hurricane is to any extent controlled by the prevailing

* F. H. Bigelow, Storms, storm tracks and weather forecasting. United States Weather Bureau, Bull. No. 20. 8°. Washington, 1897. 87 pp.

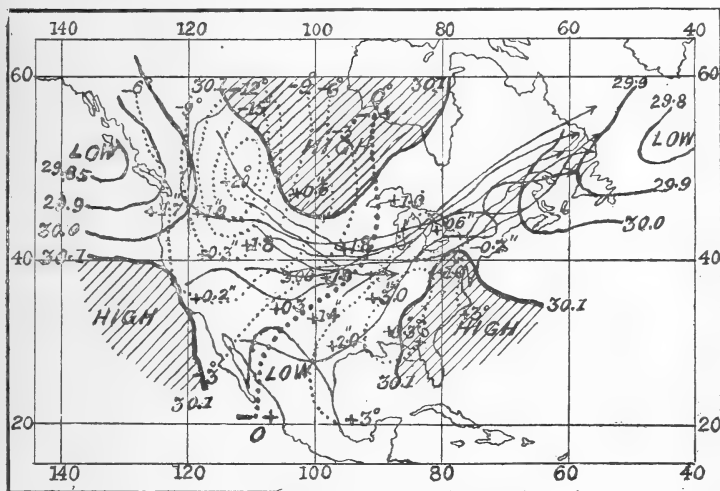
pressure over the Atlantic Ocean during the time of passage of a hurricane, I have selected from Bulletin A of the United States Weather Bureau the path of a hurricane which extended

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AVERAGE PATHS OF MARCH STORMS.

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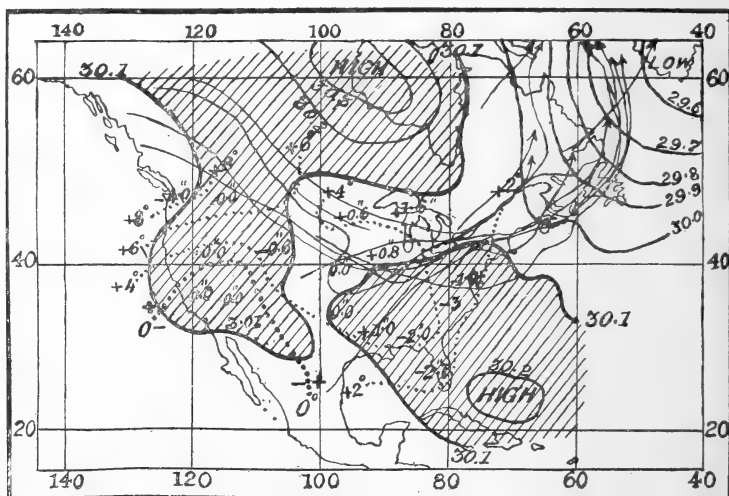


MARCH, 1897.

very far inland, and plotted it in connection with the mean September position of the Atlantic high area, together with the position of the area during September, 1886. This West Indian hurricane occupied about eleven days in its passage from

the West Indies through the Gulf of Mexico, up the Mississippi Valley and across the Lake region. The Atlantic high area extended far to the west of its usual position. Similarly the conditions for September, 1883, were charted, during which a

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These two instances, taken at random, seem to show a direct relationship between the Atlantic high area and the path of the hurricanes. It is quite probable that by charting the pressure conditions over the Atlantic Ocean at the origin and during the slow progress of a hurricane, we may be enabled to forecast more definitely its probable path across the United States.

Summary of results.—The study of March weather conditions in the United States seems to warrant the following statements :

(a) The problem of March weather in the United States is a problem of the relative preponderance of the three areas of high atmospheric pressure seen upon the chart of normal pressure and described above.

(b) The weather of the Middle Atlantic States is cold when the continental high area controls this region ; it is warm when the Atlantic high area extends its influence westward beyond the coast ; it is normal when there is a fairly equal development in strength and extent of the two high areas, in which case now one, then the other, is in control of the wind direction, bringing alternately cold and warm air to the region.

(c) A complete control of the region by either area is accompanied by a deficient rainfall. The extent and persistence of the high area defines the extent and severity of a drought.

(d) The paths of storms lie within the trough between the two high areas ; when the trough is wide the storm paths are widely scattered ; as the high areas approach one another the storm paths are contracted within narrower limits.

(e) An intelligent discussion of Pacific coast weather demands a better knowledge of the development and movements of the Pacific high area. Under normal conditions during March the weather of the Pacific Coast States is completely controlled by this high area, which sends to these regions warm winds from the ocean. The temperatures and rainfall along the North Pacific coast are far in excess of the normal for those latitudes. An abnormal development of the continental high area will lower the temperature. This will be intensified by the retreat southward or westward of the Pacific high area, and the approach of the Behring Sea low area to the neighborhood of Puget Sound ; a condition which brings about a comparatively steep gradient between the coast and the interior, and facilitates the transfer of large masses of cold air from the interior of the continent to the coast.

In order to turn to practical account the facts gathered in the foregoing paragraphs, a better knowledge of the manner in which these high areas move and their rate of movement, is

necessary. Excellent material is at hand for the study of these problems in the "Bulletin of Simultaneous International Observations" of the United States Weather Bureau, the "Synoptic Charts of the North Atlantic Ocean" of the Danish Meteorological Institute and the Hamburg Marine Observatory, and the "Charts of the Indian Monsoon Area" of the Indian Meteorological Service. It is of the highest importance to secure synoptic charts of the Pacific Ocean, charts for this vast area being at present entirely wanting. The United States Hydrographic Office has fortunately made a beginning in this direction by collecting daily observations of pressure, wind direction and state of the weather, for use in the preparation of the Pilot Chart of the Pacific Ocean, but these observations are not published and hence not easily accessible for purposes of study.

Some advance has been made in gathering telegraphic statistics for the North Atlantic since Hoffmeyer in 1879 proposed joining the islands of the ocean to the mainland in order to trace more accurately the larger atmospheric movements. In the south-western part of the ocean the chain has been completed by the recent establishment of the West Indian weather service as a branch of the United States Weather Bureau. Several most important links in the chain are still lacking, namely the Azores, Iceland and Greenland.

The necessity of a larger field of view in the study of weather sequences is steadily becoming more apparent to the meteorologist. The hope of progress in weather forecasting lies in this direction.

Johns Hopkins University, Baltimore.

ART. XLI.—*Some new Minerals from the Zinc Mines at Franklin, N. J., and Note concerning the Chemical Composition of Ganomalite*; by S. L. PENFIELD and C. H. WARREN.

THE minerals to be described in the present paper came for the most part from the one-thousand-foot level of the Parker Shaft on North Mine Hill. Unfortunately at the time that they were brought to the surface, about two years ago, the fact that several new species were being mined was not known, and a quantity of material, which it is believed would prove to be very profitable hunting ground for the new species, was thrown upon the dump and subsequently covered up. Our attention has been called to these minerals at different times by Messrs. E. P. Hancock, of Burlington, N. J., J. J. McGovern, of Franklin, F. L. Nason, of West Haven, Conn., F. A. Canfield, of Dover, N. J., and W. M. Foote, of Philadelphia, Pa., while both of the authors at separate visits to the locality have been able to collect a few specimens. The new species were found in a somewhat limited area, and it is especially interesting to note the minerals which are associated with them, for they are very unusual even for Franklin, N. J., and would seem to indicate that peculiar conditions prevailed during the period when these minerals were being formed. The associated minerals are as follows: Native lead* and copper,† clinohedrite,‡ roeblingite,§ axinite in transparent yellow crystals, willemite in exceptionally fine, transparent green crystals, vesuvianite, datolite, barite, garnet, brownish-black phlogopite and a little franklinite. The presence of axinite and datolite containing boron and of phlogopite would seem to indicate that the minerals, part of them at least, have resulted from metamorphism brought about by the action of intruded igneous masses either during the pneumatolitic period when such masses were giving off heated aqueous vapors carrying boron and fluorine compounds, or during a period when heated waters, laden with mineralizing agents, were circulating through the deposit.

1. HANCOCKITE.

This mineral was found in considerable quantity both massive and in cellular masses of a brownish-red or maroon color, and attention has already been called to it as a new species by Penfield and Foote in their description of clinohedrite.¶ Thus

* This Journal, vi, p. 187, 1898.

† Proc. Am. Acad. of Arts and Sci., xxxiii, p. 429, 1898.

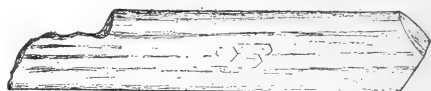
‡ This Journal, v, p. 289, 1898.

§ Ibid., iii, p. 413, 1897.

¶ Loc. cit.

far it has been observed only in very small, lath-shaped crystals, the largest being not over 0.5^{mm} in length and 0.15^{mm} in diameter, and these generally are so intimately associated with garnet, axinite and phlogopite that it was for a long time difficult to secure a specimen from which a sufficient quantity of the pure material could be obtained for the chemical analysis. The accompanying figure is a sketch of one of the crystals as seen under the microscope. The faces are striated parallel to the longer axis of the crystals, and they round into one another owing to oscillatory combinations. The terminal faces, neces-

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sarily very small, are vicinal, and it has thus far been impossible to find any crystal from which satisfactory measurements of the interfacial angles could be obtained. As may be seen from the figure the habit of the crystals is like that of epidote; that is, the prominent faces are parallel to the axis of symmetry, and the crystals are terminated by two faces corresponding to the form $n(\bar{1}11)$ of epidote. On one of the crystals it was possible to obtain approximate measurements with the Fuess reflecting goniometer by using a strong illumination of the signal and the δ ocular. The measurements, given in the accompanying table, although not sufficiently accurate for establishing an axial ratio, indicate that the forms and angles of hancockite are similar to those of epidote.

	Hancockite, Approximate measurements.	Epidote.
$c \wedge e, 001 \wedge 101 =$	$36^{\circ} 15'$	$34^{\circ} 43'$
$e \wedge a, 101 \wedge 100 =$	30 45	29 54
$c \wedge r, 001 \wedge \bar{1}01 =$	63	63 42
$r \wedge a, \bar{1}01 \wedge \bar{1}00 =$	55 30	51 41
$n \wedge n, \bar{1}11 \wedge 11\bar{1} =$	67	70 29
$c \wedge n, 001 \wedge \bar{1}11 =$	77	75 11

Although the appearance of the mineral in the hand specimen varies from a dark to a light brownish-red, single crystals, as seen with a pocket lens, have a yellowish-brown color. Crystals like fig. 1, when examined with the polarizing microscope, exhibit distinct pleochroism, yellowish-brown for vibrations parallel to b , which corresponds to the crystallographic axis b , and somewhat variable for vibrations at right angles to this direction, being delicate rose color at the attached end and

grading to pale, somewhat greenish-yellow at the terminated end. On some very small individuals the delicate rose color was observed throughout the whole length of the crystals. With crossed nicols the crystals show an extinction when their longer or symmetry axis is parallel to the plane of the polarizer. In convergent light something of the outer rings of the biaxial interference figure could be seen, accompanied by a dark bar, indicating plainly that the optical axes are in the symmetry plane. By rotating a crystal, when immersed in the potassium mercuric-iodide solution, the optical axes could be brought separately to the center of the field and their divergence $2V$ was found to be approximately 50° .

The luster of the hancockite crystals is vitreous, and the hardness is about 6.5–7. Owing to the small size of the crystals and their intimate association with garnet, axinite and willemite, considerable difficulty was experienced in finding a specimen from which a sufficient quantity of pure material could be obtained for analysis. A specimen, however, finally came to us through Mr. Hancock, consisting of a cellular mass in which the walls and the drusy lining consisted chiefly of hancockite. By crushing this specimen, picking out the small fragments and examining them with a lens, it was possible to obtain the mineral almost absolutely free from the associated garnet and axinite, which could be distinguished by their lighter color. An attempt to separate the minerals by differences in their specific gravity was not successful. The specific gravity of the carefully selected material was found to be 4.030.

Concerning the method of analysis the only points which need to be specially commented upon are the following: After separation of the silica, the lead was precipitated with hydrogen sulphide and subsequently converted into sulphate and weighed. The iron and alumina were separated from the bivalent metals by a basic acetate precipitation, reprecipitated by ammonia and weighed as oxides, the iron being estimated subsequently by means of potassium permanganate. The calcium and strontium were converted into nitrates and separated by means of amyl alcohol as directed by Browning.* Water was estimated by loss on ignition. Careful tests failed to reveal the presence of any ferrous iron. The deep color of the crystals at first suggested the idea that the mineral would be rich in manganese, which is by no means the case. The color, however, is probably due to the presence of some higher oxide of manganese which is known to impart an intense color to silicates and was estimated by the method described by Penfield.†

* This Journal, xliii, p. 50, 1892.

† Ibid., xlv, p. 291, 1893.

The results of the analysis by Warren are as follows:—

				Average.	Ratio.					Partial Analysis.
SiO ₂	30.99			30.99	.516	SiO ₂	6	SiO ₂	30.88	
Al ₂ O ₃	17.89			17.89	.173			Al ₂ O ₃	17.99	
Fe ₂ O ₃	12.30	12.37	12.33	.077	} .259 R ₂ O ₃ 3.00			Fe ₂ O ₃	12.96	
Mn ₂ O ₃	1.38		1.38	.009						
PbO	18.47	18.59	18.53	.083				PbO	17.47	
MnO	2.12		2.12	.029				MnO	2.96	
MgO	0.52		.52	.013	} .367 RO 4.26			MgO	1.02	
CaO	11.50		11.50	.205				CaO	} 15.33	
SrO	3.89		3.89	.037				SrO		
H ₂ O	1.62		1.62	.090		H ₂ O	1.06		1.62	
				100.77						100.23

The ratio of SiO₂ : R₂O₃ : RO : H₂O approximates closely to 6 : 3 : 4 : 1, which gives as the empirical formula H₂R''₄R'''₃Si₆O₂₆, or R''₂(R'''·OH)R'''₂(SiO₄)₃. The general formula is that of epidote, but the material differs from any variety of that mineral previously described in having the bivalent metals lead and strontium isomorphous with calcium. Owing to its color and the presence of manganese sesquioxide the mineral is allied to piedmontite. It will be observed that the quantity of protoxide, RO, indicated by the analysis, is a trifle high, SiO₂ : RO being 6 : 4.26 instead of 6 : 4, as it should be to satisfy the epidote formula. The analyses, however, were made with very great care, and in the determination of the calcium and strontium the separated oxides were converted into sulphates and thus found to have the correct molecular weight. The partial analysis given was made on material taken from the same specimen as used for the other analysis, but the higher oxide of manganese was not determined and strontium was not separated from the calcium.

In its chemical as well as in its crystallographic relations, hancockite is a member of the epidote group of minerals, and should occupy a position next to piedmontite in a system of mineralogy. It is especially interesting on account of the considerable quantities of lead and strontium which it contains, elements thus far observed in combination with silicic acid in only a few rare mineral species.

Before the blowpipe, hancockite fuses with intumescence at 3 to a black, slightly magnetic globule. The globule becomes more strongly magnetic if heated on charcoal. With sodium carbonate on charcoal a coating of lead oxide is obtained. Reacts for manganese with the sodium carbonate bead in O. F. The mineral is insoluble in hydrochloric acid, but, like epidote,

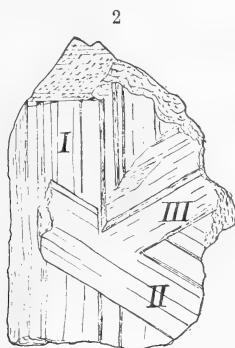
after fusion it dissolves and yields gelatinous silica upon evaporation. In the closed tube, at a high temperature, a little water is given off.

A considerable quantity of hancockite was taken from the mine at one time, and it is the most abundant of the new species described in this paper. It is named after Mr. E. P. Hancock of Burlington, N. J.

2. GLAUCOCHROITE.

This mineral was collected by S. L. Penfield in September, 1898, and was subsequently sent to New Haven for identification by Mr. W. M. Foote, who had collected several specimens of it earlier in the season. It occurs in prismatic crystals belonging to the orthorhombic system, and in columnar aggregates imbedded in a white matrix. The largest crystals thus far observed do not average over 2^{mm} in greatest diameter, while the length of some of the columnar aggregates somewhat exceeds 10^{mm}.

Isolated crystals generally show the form of a prism m (110), sometimes in combination with a second prism s (120), and thus far all attempts to find a crystal with terminal faces have proved unsuccessful. A few penetration and contact twins have been observed, the twinning plane being the brachydome (011), and



the vertical axes of the individuals crossing at angles of about 60° and 120°. Fig. 2 is an illustration of one of these penetration twins, drawn with the camera lucida as it appeared under the microscope. On the twin crystals the pinacoid a (100) is generally developed, although it was not observed on any of the simple crystals.

The prismatic faces, although bright, were vicinal, and consequently it was difficult to obtain reliable measurements of the prismatic angle. The average of a number of measurements

of $m \wedge m$, $110 \wedge 1\bar{1}0$, was found to be $47^\circ 32'$, and this angle, taken as fundamental, agreed very closely with the measurements derived from the best reflections. As terminal planes were not observed, the angle between the vertical axes of two prisms in twin position was measured under the microscope and found to be 121° . Assuming the twinning plane to be the brachydome (011), the angle of $011 \wedge 0\bar{1}1$ was thus found to be 59° , and taken as a fundamental angle. From the foregoing fundamental angles the axial ratio has been calculated, and is given below, together with the axial ratios of monticellite and chrysolite, to which species glaucochroite is closely related, it being a manganese monticellite.

Glaucochroite,	$a : b : c = 0.440 : 1 : 0.566$
Monticellite,	" " " = $0.431 : 1 : 0.576$
Chrysolite,	" " " = $0.466 : 1 : 0.586$

No reliable reflections could be obtained from the second prism s (120). Approximate measurements are $120 \wedge \bar{1}20 = 99^\circ$, calculated $97^\circ 16'$ and $m \wedge s$, $110 \wedge 120 = 17^\circ 21'$, calculated $17^\circ 36'$. A rather poor basal cleavage was detected, and measurements from this cleavage onto the prism faces gave angles of 90° .

The hardness is about 6. The specific gravity, taken with the pycnometer is 3.407. The fracture is conchoidal. The luster is vitreous and the color is a delicate bluish green, very similar to that of the aquamarine variety of beryl. Minute crystals are almost colorless, and on a few of the specimens there were small areas where the mineral exhibited a delicate pink color.

The optical orientation is $a=b$, $b=c$ and $c=a$. The plane of the optical axes is the base (001) and the acute bisectrix is normal to the brachypinacoid b (010). The double refraction is therefore negative. Prismatic crystals served as prisms for determining the indices of refraction $\alpha=1.686$ and $\beta=1.722$. These values were each derived from the mean of four independent measurements which showed considerable variation, owing to the vicinal character of the prismatic faces, but it is believed that they represent a close approximation to the true values. On a section parallel to the pinacoid (010), which measured 0.5×1.5 mm, the divergence of the optical axes for yellow light, Na flame, was measured on the Fuess axial angle apparatus as follows: $2E=121^\circ 30'$ and $2H$ in α -monobromnaphthalene $=63^\circ 27'$. From these values $2V_\gamma$ was found to be $60^\circ 53'$ and $60^\circ 49'$, respectively. The dispersion was marked $\rho > v$. From the values α , β and V , γ was calculated and found to be 1.735. The optical orientation, dispersion and

the character of the double refraction of glaucocroite are like those of monticellite as determined by Penfield and Forbes.* The indices of refraction for yellow light and the divergence of the optical axes, $2V$, of glaucocroite, monticellite and chrysolite are given below for comparison:

	α	β	γ	$\gamma-\alpha$	2 V over α
Glaucochroite,	1.686	1.722	1.735	0.049	60° 51'
Monticellite,	1.6505	1.6616	1.6679	0.0174	75° 2'
Chrysolite,†	1.661	1.678	1.697	0.036	92° 14'

Very pure material for the chemical analysis was obtained by picking out the small prismatic crystals which separated readily from the matrix. The results of the analysis by Warren are as follows :

		Ratio.		Corrected analysis.	Theory for CaMnSiO ₄
SiO ₂	31.48	.524	1.00	31.98	32.08
MnO	38.00	.535	1.02	38.60	37.97
CaO	28.95	.517	.99	29.42	29.95
PbO	1.74				
FeO	trace			100.00	100.00
	100.17				

Leaving out of consideration the small amount of PbO, which, owing to its high molecular weight, had only a slight effect upon the ratio, the ratio of $\text{SiO}_2 : \text{MnO} : \text{CaO} = 1.00 : 1.02 : 0.99$, or a very close approximation to 1:1:1. The formula of glaucochroite is therefore CaMnSiO_4 , that of monticellite being CaMgSiO_4 . With the above analysis we have given the corrected analysis, after disregarding 1.74 per cent of PbO and calculating to 100 per cent, and also the theoretical composition corresponding to the formula CaMnSiO_4 . Glaucochroite takes therefore a place in the system of mineralogy next to monticellite as a member of the chrysolite group.

Glaucocroite fuses quietly before the blowpipe at about 3·5 to a brownish black globule, and imparts no color to the flame. The powdered mineral dissolves easily in hydrochloric acid, and the solution yields gelatinous silica upon evaporation. A little of the concentrated solution, when brought in contact with a drop of sulphuric acid on a watch glass, gives a precipitate of calcium sulphate. With either the borax or sodium carbonate beads a strong reaction for manganese is obtained.

So far as known, only a small amount of glaucochroite has been found. Its crystals occur imbedded in a white matrix, nasonite (see beyond), and intimately associated with brown

* This Journal, 1, p. 135, 1896.

† Des Cloizeaux, *Memoirs de l'Institute de France*, T. xviii, p. 591.

garnet and yellow axinite. The name glaucochroite has been given to this species because of its color, from $\gamma\lambda\alpha\upsilon\kappa\acute{o}\varsigma$ = *blue-green* and $\chi\rho\omicron\iota\alpha$ = *color*.

3. NASONITE.

This material constitutes the matrix in which the crystals of glaucochroite are generally imbedded. It occurs massive, of white color, greasy to adamantine luster, hardness about 4, and hand specimens usually present a mottled or spotted appearance owing to numerous inclusions of yellow axinite and brown garnet, which are scattered rather uniformly through the massive nasonite. The material that has been examined consists of a few specimens collected by S. L. Penfield and some sent to us by Mr. W. M. Foote.

Thin sections when examined with the polarizing microscope show that the material is crystalline, and that the masses consist of an intergrowth of crystal particles, some of which are several millimeters in diameter. No pronounced cleavages were observed under the microscope, and no crystal boundaries were detected which gave any clue to the system of crystallization. In convergent polarized light, however, certain sections gave a uniaxial interference figure, and, since the massive mineral broke up at times into rude rectangular blocks, it may be inferred that the crystallization is tetragonal and that the cleavage, which is poor, is prismatic and basal. The birefringence is rather strong, and the character of the double refraction is positive.

Material for the chemical analysis was obtained by crushing a large fragment and picking out the purest material by hand. The specific gravity was found to be 5.425, and the results of the analysis by Warren are as follows:

	I	II	Average	Ratio		
SiO ₂	18.47	18.47	18.47	.308		3.00
PbO	65.84	65.52	65.68	.294		
ZnO	0.84	0.80	0.82	.010	} .516	5.03
MnO	0.90	0.76	0.83	.011		
FeO	0.10	—	0.10	.001		
CaO	11.20	11.20	11.20	.200		
Cl	2.80	2.82	2.81	.079	} .108	1.05
H ₂ O	0.27	0.26	0.26 ÷ 9	.029		
			100.17			
Oxygen equivalent of Cl			.63			
			99.54			

The ratio of $\text{SiO}_2 : (\text{Pb} + \text{Zn} + \text{Mn} + \text{Fe} + \text{Ca}) \text{O} : (\text{Cl} + \text{OH}) = 3.00 : 5.03 : 1.05$ which approximates closely to $3 : 5 : 1$, and, since two chlorine atoms are equivalent to one oxygen, this leads to the general formula $\text{R}_{10}\text{Cl}_2\text{Si}_6\text{O}_{21}$, $\text{R} = \text{Pb}$ and Ca , and only traces of Zn , Mn and Fe . Before discussing the general formula further, it may be stated that there were observed, intimately associated with the nasonite, a few particles of clinohedrite, $\text{H}_2\text{CaZnSiO}_5$, and it is probable therefore that the small percentage of zinc (0.82 per cent ZnO) was derived from a slight admixture of this latter mineral. It seems therefore best to deduct from the foregoing analysis the ZnO , and sufficient amounts of SiO_2 , CaO and H_2O to form the clinohedrite molecule. The ratio then becomes $\text{SiO}_2 : (\text{Pb} + \text{Mn} + \text{Fe} + \text{Ca}) \text{O} : (\text{Cl} + \text{OH}) = .298 : .496 : .098 = 3.00 : 5.01 : 0.99$ or almost exactly $3 : 5 : 1$. Furthermore the ratio of $\text{SiO}_2 : \text{PbO} : (\text{Ca} + \text{Mn} + \text{Fe}) \text{O} : (\text{Cl} + \text{OH}) = .298 : .294 : .202 : .098 = 3.00 : 2.97 : 2.04 : 0.99$ or, very closely, $3 : 3 : 2 : 1$. Since Fe , Mn , and water (hydroxyl) are present only in very small amounts, they may practically be disregarded, and the empirical formula expressed as $\text{Pb}_6\text{Ca}_4\text{Cl}_2 (\text{Si}_2\text{O}_7)_3$, or $\text{Pb}_4 (\text{PbCl})'_2 \text{Ca}_4 (\text{Si}_2\text{O}_7)_3$.

Below we have given the analysis, after deducting 2.16 per cent of clinohedrite, substituting for MnO and FeO equivalent amounts of CaO , for the remaining 0.09 per cent of water (hydroxyl) an equivalent of chlorine, and calculating to 100 per cent, while, for comparison, the theoretical composition corresponding to the formula $\text{Pb}_6\text{Ca}_4\text{Cl}_2 (\text{Si}_2\text{O}_7)_3$ is also given.

	Analysis corrected.	Theory.
SiO_2	18.32	18.21
PbO	67.32	67.68
CaO	11.59	11.33
Cl	3.57	3.59
	<hr/>	<hr/>
	100.80	100.81
$\text{O} = 2\text{Cl}$ .....	.80	.81
	<hr/>	<hr/>
	100.00	100.00

Before the blowpipe, nasonite is very apt to decrepitate, but if a fragment can be held in the forceps it fuses at about 2 to a semi-transparent globule, and the characteristic flame coloration of lead is obtained. In the closed tube the mineral gives a trace of water and an abundant sublimate of lead chloride, the residual mineral fusing to an amethystine glass in the bottom of the tube. The powdered mineral, when heated alone on charcoal in the reducing flame, gives a white sublimate of lead chloride distant from the assay, a yellow coating of oxide nearer,

and globules of metallic lead. The mineral is readily soluble in dilute nitric acid, and the solution yields gelatinous silica upon evaporation.

The mineral is named after Mr. Frank L. Nason of West Haven, Connecticut, formerly of the Geological Survey of the State of New Jersey.

Note concerning the Chemical Composition of GANOMALITE.

Nasonite is closely related to ganomalite, to which the empirical formula $Pb_3Ca_2Si_3O_{11}$ has been assigned, a little calcium being replaced by manganese. The foregoing formula, when doubled, may be written as a slightly basic salt, as follows: $Pb_4(Pb_2O)''Ca_4(Si_2O_7)_3$, which is like the formula of nasonite, except that the bivalent basic lead oxide radical (Pb_2O) of ganomalite takes the place of the two univalent lead chloride radicals ($PbCl$) of nasonite. The analogy between the two minerals, however, becomes still closer if two univalent lead hydroxide radicals ($PbOH$) are substituted for the bivalent basic lead oxide radical as follows: $Pb_4(PbOH)_2Ca_2(Si_2O_7)_3$, and we hope to be able to show that this is undoubtedly the correct formula for ganomalite. The amount of water necessary to yield two hydroxyls in the complex ganomalite molecule is a trifle less than one per cent, a quantity which might have been easily overlooked. In two analyses of ganomalite from Jakobsberg, Sweden, by Wiborgh, quoted by Sjögren,* neither water nor loss on ignition are recorded, while in an analysis by Lindström† a loss on ignition of 0.57 per cent is given, and, what is also very significant, the presence of a little chlorine is recorded. Lindström's analysis is as follows:

Analysis.		Ratio.		Analysis recalculated.	Theory for $Pb_4(PbOH)_2Ca_4(Si_2O_7)_3$
SiO ₂	18.33	.306	3.00	SiO ₂ 18.51	18.56
PbO	68.80	.308	3.02	PbO 69.46	68.97
MnO	2.29	.032	} .202	CaO 11.40	11.55
MgO	.11	.003		H ₂ O .63	.92
CaO	9.34	.167	} .070	100.00	100.00
Cl	.24	.007			
Ign.	.57 ÷ 9 = .063				
† X	.35				
100.03					

The ratio of $SiO_2 : PbO : CaO : (OH + Cl) = 3.00 : 3.02 : 1.98 : 0.70$ or, excepting the hydroxyl and chlorine, a very close approximation to $3 : 3 : 2 : 1$, thus agreeing with the ratio of nasonite.

* Geol. För. Förhandl., vi, p. 537, 1883.

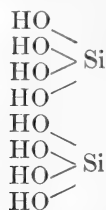
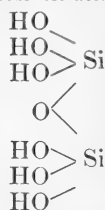
† Ibid., p. 663.

† X = CuO 0.02, Al₂O₃ 0.07, Fe₂O₃ 0.12, alkali 0.10, P₂O₅ 0.04.

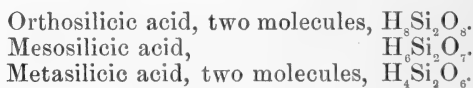
The water (loss on ignition) is low, owing undoubtedly either wholly or in part to the partial oxidation of the manganese during ignition. It is also possible that a trace of fluorine was present, since the amount necessary to bring the ratio of $(\text{OH} + \text{Cl} + \text{F})$ up to 1 would be trifling and might easily be overlooked. In connection with Lindström's analysis we have given his values recalculated to 100 per cent, after substituting an equivalent of CaO for the small amounts of MnO and MgO , an equivalent of water (hydroxyl) for chlorine, and disregarding the 0.35 per cent designated as X. The theoretical composition corresponding to the formula $\text{Pb}_4(\text{Pb.OH})_3\text{Ca}_4(\text{Si}_2\text{O}_7)_3$ is also given, and, except for the water, which is 0.31 per cent low, the agreement between the recalculated analysis and the theory is most satisfactory.

Ganomalite is tetragonal, and, in all probability, nasonite crystallizes in the same system, for, as already stated, the latter is optically uniaxial and breaks out into rude rectangular blocks, corresponding to the form produced by a combination of the prismatic and basal cleavages. The cleavage of nasonite, however, should be designated as poor, scarcely distinct, while ganomalite is described as having distinct cleavages parallel to the prism m (110) and the base. Both minerals exhibit strong positive birefringence. The specific gravity of nasonite, 5.425, is less than that of ganomalite, 5.738, which would be expected, for, although nasonite contains chlorine which is heavier than hydroxyl, ganomalite contains more lead and hence should be heavier. The percentages of lead according to theory are, respectively, nasonite 67.28 and ganomalite 68.98. Thus in their physical properties nasonite and ganomalite are closely analogous, and it may be confidently expected, on the one hand, that if crystals of nasonite are discovered they will be tetragonal, thus conforming to ganomalite, while, on the other hand, ganomalite will be found to contain water in sufficient quantity to yield with the chlorine a ratio of $\text{SiO}_2 : (\text{OH} + \text{Cl}) = 3 : 1$. The two minerals furnish an excellent example of the isomorphous relation existing between chlorine and hydroxyl in complex molecules, nasonite being essentially the pure chlorine compound but containing a trace of hydroxyl (water), and ganomalite being essentially the pure hydroxyl compound but containing a trace of chlorine. Both minerals contain a little manganese isomorphous with the calcium.

The acid, $\text{H}_6\text{Si}_2\text{O}_7$, of which nasonite and ganomalite are salts, is intermediate between orthosilicic acid, H_4SiO_4 , and metasilicic acid, H_2SiO_3 , and it may be regarded either as equivalent to their algebraic sum, or as derived from two molecules of orthosilicic acid by taking away one molecule of water. The latter relation may be expressed as follows:

Two molecules of
orthosilicic acid.Intermediate or
mesosilicic acid.

The intermediate acid $\text{H}_6\text{Si}_2\text{O}_7$ is one which has been recognized by mineralogists, but its salts have not generally received a prominent place in the systematic classifications of silicates, because they are not very numerous. Groth* calls attention to the acid and its salts, and has given the name "*Diorthokieselsäure*" to the acid. Clarke† also has discussed the chemical relations of the minerals of this group, adopting Groth's name *diorthosilicic acid*, and calling the minerals *diorthosilicates*. The name *diorthosilicic* seems, however, inappropriate, since $\text{H}_6\text{Si}_2\text{O}_7$ is not an orthosilicic acid as the name signifies, but a derivative of orthosilicic acid. We feel, therefore, warranted in suggesting new names, *mesosilicic* for the acid and *mesosilicates* for its salts, the prefix *meso* being derived from μέσος, signifying middle or between. The intermediate relation of mesosilicic acid is evident from the following:



The mesosilicates are classed by Dana in the small group of "Intermediate Silicates" on page 416 of his *Mineralogy*, and by Groth as "*Intermediäre Silikate*" on page 138 of his *Übersicht der Mineralien*.

The commonest mesosilicate is iolite, the composition of which may be expressed as a slightly basic salt, as follows: $(\text{Mg, Fe})_4\text{Al}_6(\text{Al, OH})_2(\text{Si}_2\text{O}_7)_5$, although the two hydroxyls may be in combination with the bivalent metals instead of with the aluminium. One of the few lead silicates, barysilite, $\text{Pb}_3\text{Si}_2\text{O}_7$, is a normal salt of mesosilicic acid, as is also the Franklin mineral hardystonite, $\text{Ca}_2\text{ZnSi}_2\text{O}_7$, recently described by Wolff.‡ Hardystonite is said to occur at the Parker shaft, North Mine Hill, but we have not yet observed it associated with any of the new minerals described in the present paper.

* Tabellarische Übersicht der Mineralien, IV Auflage, pp. 105 and 140.

† Constitution of the silicates; Bull. of U. S. Geolog. Survey, No. 125, p. 81.

‡ Proceedings of the Am. Acad. of Arts and Sci., xxxiv, p. 479, 1899.

4. LEUCOPHÆNICITE.

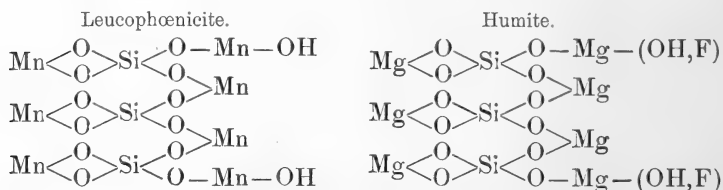
This mineral made up the larger part of a specimen about two inches in length and breadth by one inch in thickness, which was found by Mr. J. J. McGovern of Franklin, and given to C. H. Warren in 1897. It has also been observed in small amount on a few specimens sent to us by Mr. W. M. Foote. The mineral has a crystalline structure, vitreous luster, hardness about 5·5–6, and is conspicuous on account of its light purplish-red or raspberry color. It was supposed at first to be clinohedrite, rather deeply colored by manganese. It is intimately associated with willemite of almost gem-like quality and beautiful light green color, and with small idiomorphic crystals of brown vesuvianite, showing prisms of the first and second order, pyramid of the first order and base. Occasional crystal faces were observed on the leucophænicite, but none which gave any clue to the system of crystallization.

When small fragments of the mineral are imbedded in balsam and examined with the microscope it may be seen that the fragments are mostly irregular, although some are flat and appear to lie upon imperfect cleavage faces. There also may be seen irregular cracks indicating a second but not distinct cleavage. In polarized light the extinction seemed to be slightly inclined to the direction of the second cleavage, and in convergent light an optical axis was observed near the limit of the field. The fragments showed a slight pleochroism, pale rose for vibrations parallel to the direction of cleavage, and colorless at right angles to this direction. These properties indicate that the material probably crystallizes in one of the inclined systems, although wholly satisfactory conclusions could not be drawn.

Very pure material for the chemical analysis was obtained by crushing a portion of the best specimen, and selecting the purest particles by hand. The specific gravity was found to be 3·848. The results of the analysis by Warren are as follows:

	I.	II.	Average.	Ratio.	
SiO ₂ -----	26·31	26·41	26·36	·439	} 3·03
MnO -----	60·59	60·67	60·63	·854	
ZnO -----	4·03	3·72	3·87	·047	
FeO -----	----	----	trace	----	
MgO -----	0·21	----	0·21	·005	} 1·015 7·00
CaO -----	5·64	5·70	5·67	·101	
Na ₂ O -----	0·39	----	0·39	·006	
K ₂ O -----	0·24	----	0·24	·002	
H ₂ O -----	2·70	2·58	2·64	·146	1·01
			<hr/> 100·01		

Letting R stand for the metals (chiefly manganese) the ratio of $\text{SiO}_2 : \text{RO} : \text{H}_2\text{O}$ is 3.03 : 7.00 : 1.01, or a close approximation to 3 : 7 : 1, and this leads to the general empirical formula $\text{H}_2\text{R}_7\text{Si}_3\text{O}_{14}$. Since water is not expelled from the mineral much below a red heat, the hydrogen must exist in the form of hydroxyl, and, consequently, the foregoing formula may be written $\text{R}_6(\text{R.OH})_2(\text{SiO}_4)_3$ or as a basic orthosilicate, exactly equivalent to humite except that no fluorine is present. Considering the base wholly as manganese, the following is suggested as a structural formula of the mineral, which certainly appears simple and reasonable, and for comparison the structural formula of humite is also given.



Leucophœnicite is therefore a manganese humite, but it contains no fluorine isomorphous with the hydroxyl. As humite is a magnesium mineral resulting from metamorphism due to fumerole or pneumatolitic action, so leucophœnicite is a similarly constituted mineral, produced probably by like causes at a locality where manganese was abundant. It is probable that the crystallization of leucophœnicite is analogous to that of the minerals of the humite group, and, since the examination of fragments of leucophœnicite in polarized light indicated one of the inclined systems (page 351), it may be inferred that its crystallization is monoclinic, with $\beta = 90^\circ$, analogous to chondrodite and clinohumite, rather than orthorhombic like humite. Furthermore, the discovery of this mineral suggests the possibility of finding a series of manganese compounds, corresponding to prolectite, chondrodite, humite and clinohumite. Attention may also be called to the fact that Jannasch and Locke* have described a variety of humite from Valais, Switzerland, exactly analogous to leucophœnicite in that it contains no fluorine.

Before the blowpipe, leucophœnicite fuses quietly at about 3 to a brownish black globule. In the closed tube it yields a little water. Reacts for manganese with the fluxes. The powdered mineral dissolves very easily in hydrochloric acid, and the solution yields gelatinous silica upon evaporation.

* Zeitschr. für anorganische Chemie, vii, p. 92, 189.

The name leucophœnicite has reference to the color of the mineral, and was derived from λευκός = pale or light and φοίνιξ = purple-red.

There are other minerals from the locality, some of them evidently new, which have been partially examined, and it is hoped that a full description of them may be given in a future article.

In closing we desire to express our thanks to those gentlemen, named at the beginning of this article, who have generously supplied us with material for carrying on this investigation, and especially to Mr. W. M. Foote, who spent some weeks collecting at the locality in the summer of 1898 and who has called our attention to a number of interesting specimens and associations.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School of Yale University, September, 1899.

ART. XLII.—*The Action of Acetylene on the Oxides of Copper*; by F. A. GOOCH and DEFOREST BALDWIN.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXXIX.]

IN a recent paper by Erdmann and Köthner* an account is given of the formation of a peculiar, light-brown, highly voluminous substance by the action of acetylene below 250° C. upon cuprous oxide, or even (though more slowly) upon copper. The product obtained by passing acetylene during eighteen hours over 1 grm. of cuprous oxide (prepared from copper sulphate, grape sugar, and sodium hydroxide) amounted to 7 grms. and filled a space of nearly 300^{cm}³. At higher temperatures a black carbonaceous mass is the result, and at red heat (400°–500° C.) carbon is deposited in graphitic condition. The light-brown fluffy material yielded cuprous chloride to hydrochloric acid, a distillate from its mixture with zinc dust possessing the characteristics of naphthene or, at higher temperature and under rapid heating, aromatic compounds among which naphthalene and a kresol were indicated. Erdmann and Köthner classify this body as a very complex but non-explosive copper acetylene (acetylen-kupfer), and from their analyses deduce the formula $C_{44}H_{64}Cu_3$. Apart from the unusual constitution of this symbol, its most striking peculiarity is that it implies a loss of carbon, rather than hydrogen, from the acetylene in the reaction with cuprous oxide—a condition of affairs which would be most remarkable in the light of Campbell's experience,† according to which acetylene passed over palladinized copper oxide yielded water at 225°–230° and carbon dioxide only when the temperature rose to 315°–320° with the formation of a black deposit. Upon scrutinizing the figures of Erdmann and Köthner with care, however, it appears that the formula given by these investigators rests upon some oversight in calculation: the ratio of carbon atoms to hydrogen atoms proves to be actually, according to the data given, 6.45 : 5.70; which means, of course, that the new product is deficient, as would be expected, in hydrogen (not in carbon) as compared with acetylene.

As to the content of the new substance in copper, the analytical data are unfortunately ambiguous: for we note the weights found of *copper oxide* converted into percentages of *copper* without preliminary reduction. If the fault is typographical and in the analytical data, the calculated percentages of copper being correct, the average percentage of copper amounts to 15.43: if, on the other hand, the analytical data

* Zeitschr. für anorg. Chem., xviii, 49.

† Amer. Chem. Jour., xvii, 690.

are right, the error being in their reduction, the percentage of copper amounts to 12.92. In the one case the summation of the analysis leaves a deficiency of about 1.5 per cent, and in the other of about 4 per cent, which in either case may really represent oxygen in the substance. This condition of matters leaves the "acetylen-kupfer" of Erdmann and Köthner in uncertain standing.

More than thirty years ago it was noticed by Berthelot* that acetylene is polymerized by heat or decomposed partially into carbon and hydrogen, and that such action takes place more readily and at lower temperatures in presence of metallic iron with production of carbon, hydrogen and compounds different from those formed by heat alone.

Moissan and Mouren† have observed the incandescence of acetylene passed over finely divided iron, cobalt, nickel or platinum at the ordinary temperature, with production of carbon, hydrogen, and pyrogenic compounds, and have found the occasion of such behavior in the porosity of the metals employed.

It would seem natural, however, that the presence of oxygen, free or combined, may also play a considerable part in such phenomena, just as appears to be the case in the peculiar action recorded by Gruner‡ of carbon monoxide upon iron reduced by hydrogen, which, as Moissan has shown,§ is produced pure only with the greatest precaution and generally carries a large proportion of ferrous oxide. The fact that the "acetylen-kupfer" of Erdmann and Köthner is produced more easily by the action of cuprous oxide upon acetylene than by the action of metallic copper upon acetylene, suggests that it may be the oxidizing power of the cuprous oxide which gives to this reagent its peculiar activity. The question arises, therefore, as to whether the copper is in reality an essential constituent of the compound of Erdmann and Köthner.

In our experiments upon the action of acetylene upon the oxides of copper (and other elements) we have conducted the gas (made in the ordinary way by the action of water on calcium carbide, and kept over water) over the oxide contained in a porcelain boat placed within a glass tube, 2^{cm} in diameter and 50^{cm} long, which was heated over a small combustion furnace. The glass tube was fitted at each end with a rubber stopper, one carrying a smaller tube for the introduction of the acetylene and a high-temperature thermometer so held that its bulb rested horizontally immediately over the boat containing the oxide, while the other was fitted with a water-trap. In the

* Ann. d. Chim. et d. Phys. [4], ix, 448.

† Compt. Rend., cxxii, 1240.

‡ Ann. d. Chim. et d. Phys. [4], xxvi, 5.

§ Ann. d. Chim. et d. Phys. [5], xxi, 199.

preliminary experiments no attempt was made to purify the acetylene employed other than to keep it over water, or, since water is a product of its action upon oxides, to dry it: in later experiments to secure products for careful analysis it was dried and purified with care.

We found that 225°C . is the temperature most favorable for the formation of the voluminous product obtained by acting with acetylene upon cuprous oxide as described by Erdmann and Köthner. At this temperature the tube is choked rapidly with the fluffy product and water forms, but, as Campbell found in his experiments upon palladinized copper oxide, no appreciable amount of carbon dioxide is produced. The content of the product in copper varies in the sample and in different experiments, our results lying between 1.54 per cent and 24.21 per cent of the substance taken for ignition.

It appeared, also, that the action of acetylene upon cupric oxide is precisely similar to that upon cuprous oxide excepting the evident reduction of the former oxide early in the action. The amount of copper in the product of such action varied in our experiments from 6.53 per cent to 21.30 per cent. In one case the experiment of re-submitting to the action of acetylene a product containing 9.34 per cent of copper was made with the result that a new growth of the substance formed which on analysis yielded 3.87 per cent of copper.

A roll of copper gauze carefully reduced in hydrogen and then oxidized at one end in the outer flame of a Bunsen burner gave, when acted upon by acetylene at 225° – 250°C ., the characteristic deposit upon the oxidized end only, the unoxidized end being merely discolored.

These results go to show that, while metallic copper may at comparatively high temperatures induce the polymerization of acetylene, it is an oxidizing action which starts at moderately low temperatures the formation of the peculiar derivatives under consideration. Thus we find that ferric oxide heated in acetylene at temperatures varying from 150° to 360° , according to circumstances, darkens, glows, and gathers with evolution of heat a dark carbonaceous deposit. In the products of such action we have found the content of iron varying from 2.80 per cent to 5.86 per cent.

Silver oxide, too, acts upon acetylene: thus, in one experiment, action was evident at the ordinary atmospheric temperature, a violent explosion, which completely shattered the boat and scattered metallic silver upon the sides of the glass tube, following before the temperature reached 100° .

In the locally violent explosion of the last experiment we have evidence of the formation in the early stage of an acetylides which is decomposed later when the temperature of disso-

ciation is reached. In the experiments with the oxides of copper and iron the temperature at which the acetylene begins to act is evidently above the point at which sensitive acetylides would naturally dissociate, and we have in the observed phenomena no evidence of the formation of such compounds of copper and iron under the conditions of experimentation.

In experiments (1) to (3) of the following table are given the results of the analysis of several products obtained by conducting acetylene (purified by passing through a solution of mercuric chloride in hydrochloric acid and dried over caustic potash) over pure cuprous oxide. The temperature was kept in these experiments at 225°, and in the course of a half hour the tube was choked completely by material compacted by the pressure to (1) a spongy mass of light-brown color on the exterior next the walls of the tube, (2) darker within and (3) nearly black in the bottom of the boat, where the cuprous oxide lay originally.

In experiments (4) and (5) the substances analyzed represent the products of the action of acetylene (not specially purified) on cupric oxide.

Weight of substance taken. gram.	Found.			Calculated.			
	CO ₂ gram.	H ₂ O gram.	CuO gram.	C gram.	H gram.	Cu gram.	O by difference gram.
(1) 0.1170	0.3978	0.0673	0.0022	0.1085	0.0075	0.0018	—0.0008
(2) 0.2247	0.7489	0.0979		0.2042	0.0109		
(3) 0.1096	0.3678	0.0488	0.0045	0.1003	0.0054	0.0036	0.0003
(4) 0.1360	0.4116	0.0579	0.0182	0.1123	0.0064	0.0146	0.0027
(5) 0.1188	0.3098	0.0461	0.0317	0.0845	0.0051	0.0253	0.0039

		(1)	(2)	(3)	(4)	(5)
Per cent of carbon	....	92.74	90.88	91.51	82.57	71.13
“ hydrogen	-	6.41	4.85	4.93	4.71	4.29
“ copper	---	1.54		3.29	10.74	21.30
“ oxygen	----			0.27	1.98	3.28
		100.69		100.00	100.00	100.00

The oxygen present in these products is obviously proportional to the amount of copper and is never more than enough to be completely accounted for upon the supposition that some of the original oxide taken still holds its oxygen. So far as the analyses show, the product of lightest color (1) contains very little copper and no oxygen; the darkest product (3) obtained from the cuprous oxide contains oxygen corresponding to a mixture of two parts of copper with three parts of cuprous oxide; the oxygen in the products of (4) and (5).

obtained by acting upon cupric oxide is approximately enough to correspond to a mixture of cuprous and cupric oxides in equal proportions. This fact, taken in connection with the great range of variation in proportion and the minimum to which the copper falls in the product, which would be least likely to include contaminating metal or oxide, suggests very strongly the probability that the oxygen present is in union with copper and that the copper is held mechanically as metal or oxide and is not the essential constituent of an organic compound. Leaving out of consideration, therefore, the copper and copper oxides, and calculating the composition of the products assumed to consist essentially of carbon and hydrogen, we derive the following statement:

	(1)	(2)	(3)	(4)	(5)
Per cent of carbon ----	93.54	94.93	94.88	94.60	94.31
Per cent of hydrogen --	6.46	5.07	5.12	5.40	5.69
	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00	<hr/> 100.00

These figures correspond to symbols varying from $C_{12}H_{10}$ to nearly $C_{16}H_{10}$, with an average approximating $C_{14}H_{10}$, the symbol of anthracene or paranthracene. The analytical data of Erdmann and Köthner point in the average to a product corresponding more nearly to the first of these symbols than to either of the others. The product is doubtless variable with the temperature and the activity of oxidation. Thus, in one experiment in which acetylene was passed over ferric oxide the action began at 365° with incandescence, as described by Moissan and Moureu,* and the analysis of the product (carbon = 91.53, hydrogen = 1.36, Fe = 5.85, O = 1.26) indicates a proportion of carbon to hydrogen about four times as great as that of the average product of action at 225° on the oxides of copper.

Finally, we find no evidence that the product of the action of acetylene on the oxides of copper under the conditions of our experimentation is other than a mixture of a hydrocarbon or hydrocarbons with metallic copper or an oxide of copper, and, probably, in the darker preparations, some free carbon.

* Loc. cit.

ART. XLIII.—*Andesites of the Aroostook Volcanic Area of Maine*;* by HERBERT E. GREGORY.

ANDESITES are rare rocks in the eastern United States, but are the most abundant extrusives so far found in northern Maine. They form prominent hills and determine the general topography in some places, while in others they are represented by isolated remnants among the sedimentaries. The greater number of occurrences are of lava and breccia, but andesitic ash and tuff are also found well developed. In the following descriptions only the more important localities will be dealt with in detail. The andesites are located in Aroostook County in the townships of Chapman, Mapleton, and Castle Hill, where they constitute prominent ridges, known as Edmund's Hill, Hobart Hill and Castle Hill, and several less noticeable masses.

Field Description.

Edmund's Hill Andesites.—Edmund's Hill is situated in Chapman township near the middle of the north township line, and is simply the highest part of a ridge running N.-S. for several miles. The hill itself rises some 200 feet above the road at its base and presents the outline of a drumlin—so evenly has it been graded at each end. The trees, brush, talus, and glacial deposits entirely conceal the formations about the base of the hill, and it is only after climbing half the distance to the top that the bare rock is found in place. In climbing up the west side of the hill fragments of fossiliferous sandstone were found amongst the andesite blocks, and about 100 feet below the top the sandstone ledge outcrops. The thickness and extent of the sandstone could not be determined accurately because covered in so many places with heavy blocks and small fragments of the igneous rock fallen down from above. The contact was not seen. The entire top of the hill is of augite-andesite. The main mass is uniform in texture and cut by cleavage cracks into large blocks, which, when they fall down the slope, remain as huge masses. The south and north ends, however, and part of the west side are quite different. Here the rock is split up into long, thin slabs by a set of parallel cracks remarkably uniform in direction and length, and they retain their parallelism even when the rock is folded or faulted. Cross cleavages intersect these cracks every few feet,

* A portion of a thesis on the "Geology of the Aroostook volcanic area of Maine" presented for the doctorate degree at Yale University in 1899. The full report will appear later as a publication of the U. S. Geological Survey, to which, under the direction of Prof. H. S. Williams, the author owes the opportunity of making the investigations here recorded.

so that when the rock is loosened it comes out in flat slaty pieces one-quarter inch or so in width and several inches or even feet in area. The whole appearance is that of thin-bedded sedimentaries which have been folded and faulted. The general direction of these cleavage planes is N. 30° E. on north end and N. 35° E. on south end with a dip southeast at a high angle. The fault planes strike N. 70° E. and besides their effect at the ends of the hills in cutting out the thin slabs they occur all along the west side, each indicating a slight movement. It seems probable that the Edmund's Hill ridge owes its origin in part to the formation of a fault block.

The outlying knobs and hills to the east of the main mass are also of andesite, usually microcrystalline, but sometimes porphyritic. The igneous rock does not extend far to the west, but is replaced by arenaceous slates, and while no precise boundaries of the formation were determined, the field relations suggest that the hill is the remnant of a lava flow over the eroded and upturned edges of sandy rocks of Silurian age.*

Andesites of Hobart Hill.—This hill is an isolated mass of andesite forming a prominent feature in the landscape as one looks west from Presque Isle village. It is situated partly in Mapleton and partly in Chapman townships, and is surrounded entirely by low, poorly-drained swamps and forest lands, and visited only for lumber and tan-bark, which are secured in limited quantities during the winter season. The hill is about $1\frac{1}{4}$ miles long and $\frac{3}{4}$ miles wide, and rises quite abruptly above the plain to a height of 300 feet as a single well defined mass without branches or outlyers. The sides are everywhere quite steep, and in places present cliffs forty to fifty feet high. The top is bare only where fire has recently destroyed the vegetation. The talus slopes present a confused mass of large and small blocks of andesite which entirely conceal all outcrops except where cliffs are exposed. On the west and north sides numerous boulders of red sandstone and conglomerate are piled along the slope and mingled with the volcanic material. These were traced to their parent ledges scarcely a half mile to the north, and the boulders serve to cover the contact of the andesite with the Mapleton sandstone.† Specimens collected from various places on the hill show but slight differences in composition and texture except the rock from the northwest corner, which is a breccia of andesitic fragments and

* The sandstone at Edmund's Hill contains an EoDevonian fauna which corresponds closely with that of the Gaspé sandstone. I have given it the name Chapman sandstone.—H. S. Williams.

† The "Mapleton sandstone" here referred to is a massive, and in places coarse, red sandstone, in which plants (*Psilophyton*, etc.) have been found. It is of Devonian age but somewhat younger than the Chapman sandstone.—H. S. W.

seems to be situated along a fault line. As was the case with Edmund's Hill, so here, no actual contact between formations was observed, but the sedimentaries were traced to the very base of the hill, and the facts indicate that the hill is a remnant of a lava flow.

Andesites of South Mapleton.—In addition to the prominent hills of andesite just mentioned, there are some ten or twelve less conspicuous outcrops in the southern part of Mapleton township crossed by the Mapleton-Presque Isle road and located in the fields to the north and the south of this road. They occur usually as narrow ridges, and seem to be remnants of lava flows which occupied former valleys, but are now left standing because of the erosion of the sedimentaries on both sides.

Andesites of Castle Hill.—Castle Hill is the local name for the northern end of the high, narrow ridge extending N.-S. across the township with the same name. While not such a conspicuous feature as Haystack Mountain at the southern end of the same ridge, it forms the most considerable prominence on the immediate bank of the Aroostook River along which route all the early travel lay, and hence was an important landmark to the first settlers. There is no common local usage as to the limits of Castle Hill, and in this report the term will be applied to the masses of andesite and volcanic clastics which lie between the Aroostook River and the "State Road" from Ashland to Presque Isle. It covers an area $2\frac{1}{2}$ miles long varying in width from $\frac{1}{2}$ to $\frac{3}{4}$ mile, and is partly in Castle Hill township and partly in Wade plantation. The wagon road crosses the hill at its southern end, where it rises little higher than the surrounding plain. The eastern side has a gentle slope, and is cut up into several low knobs by small streams, so that the ridge effect is not apparent. The west side is formed by Welt's brook and the Aroostook River, which at this point is forced by it to take the abrupt backward turn so noticeable on the map. Calcareous and arenaceous slates are exposed in the bed of the river, while a short distance back steep slopes and cliffs of lava and ash rise to a height of several hundred feet. The hill is densely wooded and in places swampy except at the southern end and along the east side. At these points the bare rocks are occasionally exposed and present a great variation in character. In one place heavy ledges of gray andesite are exposed, particularly on the knobs occupying the northwest and southeast corners of lot 31. Again in the woods east of the mouth of Welt's brook is an outcrop of black silicified tuff between slates. On the southeast corner of the hill are loose ash beds containing fossils, coarse and fine volcanic breccias, and pumiceous lava in quite fresh condition. Where

the glaciers have planed off the old lavas and they have been protected from weathering, the outlines of bombs and pillows are plainly revealed, and when weathered these bombs are loosened and drop out as oval or egg-shaped bodies with amygdaloidal surface and denser interior, and lie about thickly strewing the fields. In one place there is a cistern-like depression some ten feet deep and thirty feet in diameter made in the solid andesite, while about it are piled close at hand a great number of very vesicular bombs and much glassy and brecciated ash. The whole appearance suggests a small blowhole made by a single explosion. The striking fact about all the volcanic accumulations in the Castle Hill region is their freshness and their unmistakable character.

Petrography.

Generally speaking, the andesites of this region belong to well-recognized varieties widely distributed over the earth and differ in no important particulars from the type rocks of their class. There are varieties found here, however, which are intermediate between andesites and trachytes and also occurrences with dacite facies. The exposures are numerous and easy of access and the specimens are no more altered in composition than if they were Tertiary lavas instead of Paleozoic.

Augite-Andesite—Macroscopic description.—The largest and best single exposure of andesite in this region is of this variety and forms the main mass of Edmund's Hill. It does not occur as a solid compact mass, but is broken by cleavage and shearing planes into large blocks on top, and into plates and slated material at the ends of the hill. This slated and seemingly bedded appearance, which is so unusual in an igneous rock, is the most marked peculiarity of the structure of the hill. In a few places the rock is seen to contain embedded angular pebbles of glass and baked siliceous material which stand out when it weathers; and in other places the rock presents a banded surface of gray and brown giving the appearance of bedding, but which prove on examination to be varying stages of decomposition along potential cleavages. With these exceptions the exposed rock has a uniform appearance, gray where weathered, black where fresh.

Andesites are so well known that an extended macroscopic description is unnecessary and will not be attempted. The hand specimen appears as a black, basaltic-looking rock, generally dense, with a stringy effect and sprinkled over with glassy feldspar 2^{mm} and less in length. The weathered surface is a layer of spongy, gray-brown material in which the pores are made by the decay of the larger feldspars. At the east end of

the hill the rock is much lighter in color and numerous white feldspars give it a more porphyritic appearance.

Microscopic.—As with the hand specimen, so microscopic examination reveals the composition and structure expected of a typical andesite. Magnetite, apatite, pyroxene, plagioclase, and orthoclase are the original minerals present. The plagioclase crystals range in size from laths 2^{mm} in length down to the very fine ones in the groundmass, but the larger ones are not abundant and do not give the rock a porphyritic aspect. The plagioclase forming the crystals outside the groundmass was determined by Michel Lévy's method to be labradorite; but the measurements indicated two labradorites with the formulæ: Ab_3An_4 and Ab_5An_6 . The larger feldspars show strongly marked zonal banding with occasionally as many as eight distinct zones, which decrease in basicity from the center outward, but with the original albite twinning running through the whole series. This albite twinning shows in nearly every feldspar lath with great distinctness, and twins on the pericline and manebach laws also occur. The carlsbad twins present are often with one-half dropped much below the other, and all the twinning is more or less along irregular ragged lines and with unsymmetrical development. None of the feldspars are entirely fresh, but are kaolinized along the cleavages and zonal boundaries, or entirely altered to kaolin and calcite except their outer borders. They also show irregular cracks other than cleavage along which strain has been relieved. Glass inclusions, arranged without order, are numerous and stand out prominently in the clearer parts of the feldspars. Orthoclase was not found outside the groundmass except as forming the wide outer rim of the zonally-built plagioclases.

The Pyroxenes are of both monoclinic and orthorhombic varieties. The monoclinic is an augite, light colored in thin section and having an average extinction on prism sections of 42° . The basal sections are quite fresh and show the cleavage parallel to the prism. The pinacoids are more developed than the prism faces and give the appearance of a square with truncated corners rather than the more common octagonal effect. The prism sections vary from stout forms to those five or six times as long as broad. In places many small pieces are arranged in parallel position and separated by alteration products in such a way as to suggest the presence of augite phenocrysts of which these fragments are the remnants. The orthorhombic pyroxenes are represented in the darkest colored rocks by a few basal and prism sections, but in the gray varieties it constitutes fully half of the pyroxenes present. It is very light colored, not at all pleochroic, and is at times partly eaten away and again occurs as parallel intergrowths with the

augite. It seems to be a variety poor in iron, is optically +, and hence referred to enstatite. In the fresher rock specimens the cleavage cracks and borders of the enstatite often show the presence of a red-brown fibrous mineral. In the more weathered rocks this mineral assumes a prominent role. It is here found intergrown with augite and forming fibrous laths with parallel extinction. Its pleochroism is distinct with a = light brown, c = light green. The presence of this mineral in a slide seems to be in proportion to the absence of the orthorhombic pyroxene, and this fact together with its shape and optical properties point to bastite and make the supposition plausible that the red-brown mineral is the present representative of the original orthorhombic pyroxene. The magnetite is present in grains or dust aggregates, and the apatite occurs in needles, laths, and rounded sections within the feldspars.

The *groundmass* consists essentially of feldspar laths, long, narrow, with ragged outline and split ends, arranged with trachytic structure tending toward the hyalopilitic, and with flow phenomena developed in places. No close distinction can be drawn between the groundmass feldspars and those which rise slightly above it, as all sizes are represented grading up to the very largest ones present. Optical measurements on some of the freshest pieces in the groundmass proved them also to be labradorite, although orthoclase must also be present as demanded by the analysis. Besides the feldspars, augite grains are scattered abundantly throughout and small areas of brown glass, occasionally with bubbles, also occur. The whole slide is darkened by iron dust, both magnetite and limonite or göthite. The rock is, however, in a remarkably fresh state considering its age and position, and its character is unmistakable.

Analysis.—The analysis of this rock made by Dr. W. F. Hillebrand of the U. S. Geol. Survey is given in column I below and with it analyses (columns II–VI) of well known andesites from other localities are given for comparison.

From a study of the tables it becomes apparent that the Edmund's Hill rock presents no points of distinction from recognized types found elsewhere, and the tables could be greatly enlarged by the addition of closely similar analyses. The analysis in column VII requires some notice. The rock is described as a red andesite with "rather basic" feldspars and with calcite and magnetite present. The altered condition of the rock made accurate optical determination impossible. In discussing the analysis the writer says (l. c. p. 34), "In its mineralogical composition, this rock approaches the basaltic type but, as the analysis shows, is somewhat too acid. The olivine phenocrysts, moreover, are not very numerous and there

	I	II	III	IV	V	VI	VII
SiO ₂	61.40	61.58	61.29	61.04	61.45	61.17	63.25
Al ₂ O ₃	16.59	16.96	17.68	15.72	15.07	17.74	14.89
Fe ₂ O ₃	2.13	1.75	6.03	5.03	4.46	1.78	6.54
FeO	3.05	2.85	.30	2.15	1.18	3.51	none
MgO	2.73	3.67	2.45	3.61	3.02	2.76	.82
CaO	6.17	6.28	5.61	5.34	5.37	5.90	.59
Na ₂ O	3.83	3.94	4.28	4.02	4.00	3.79	4.47
K ₂ O	1.34	1.28	1.38	2.66	1.22	1.71	4.78
H ₂ O—105° .....	.82	.24					
H ₂ O+105° .....	.88	1.06	.96	.58	1.23	.83	2.67
TiO ₂ .....	.79	.49	.65			.45	trace
ZrO ₂	none						
Cr ₂ O ₃	trace					none	
V ₂ O ₅ .....	.02						
NiO	trace						
MnO .....	.13	trace			none	.12	
BaO .....	.02	.03				.06	
SrO	trace?	trace				.04	
Li ₂ O	trace	trace			.05	trace	
P ₂ O ₅ .....	.20	.22			trace	.14	.61
CO ₂	none						.78
Cl	?						
Fl	?						
FeS ₂	none				(SO 3 .29)		loss .53
	100.10	99.23	100.63	100.15	100.14	100.00	99.93

I. Andesite, Edmund's Hill, Aroostook Co., Maine. Analysis by W. F. Hillebrand.

II. Hornblende andesite, Mt. Shasta, Cal. Analysis by N. H. Stokes, Bul. U. S. Geol. Survey, 148, p. 190.

III. Hornblende dacite, Anzeion, Ægina. Analysis Dr. A. Röhrig, H. S. Washington, Jour. of Geol., vol. iii, p. 150.

IV. Pyroxene andesite, Peñon de Pitayo, United States of Columbia. Kuch: Geol. Studien in der Republik Colombia, Pt. I. Berlin, 1892.

V. Pyroxene andesite, Agate Creek, Yellowstone National Park. Analysis by Whitfield, U. S. Geol. Survey, Bul. 148, p. 134.

VI. Hypersthene andesite, Crater Peak (Lassen Peak Region). Analysis by W. F. Hillebrand. U. S. Geol. Survey, Bul. 148, p. 197.

VII. ? Andesite, Fox Islands, Maine. Analyses by E. W. Magruder and W. A. Jones in Johns Hopkins University Laboratory. G. O. Smith, Geol. of Fox Islands, Maine. Presented as a thesis, Johns Hopkins University, 1896.

is reason to regard this as simply an olivine-bearing phase of the andesite." The description is of an andesite, but there are discrepancies between the description and the analysis. No ferrous iron is present to form magnetite, and if the small amount of lime forms calcite, basic feldspars could not be produced. And even if the whole 0.59 per cent of lime were present as andesine or labradorite the amount is far too small for an andesite. According to the generally accepted usage among petrographers, a rock with such a high percentage of soda and potash with little lime and magnesia would be classed as a trachyte or more closely, an ægerine-trachyte.

Hornblende-andesite.—The largest single mass of this rock is Hobart's Hill, and the freshest and most typical specimens are from this hill and from the west bank of the Presque Isle near the northwest foot of the hill, where quarrying was attempted at one time. The hand specimen shows a very dark gray, almost black, rock, fine-grained, but with a somewhat porphyritic appearance caused by the occasional feldspar crystals which rise above the general groundmass and reflect light well from their glassy cleavage faces. Some few feldspar laths attain a length of 5–6^{mm}. The rock breaks out into tabular blocks along the cleavages and weathers to a brownish gray color.

Microscopic description.—In thin section the microscope reveals magnetite, apatite, titanite, rarely a zircon lath, possibly augite, hornblende, plagioclase, and orthoclase together with considerable secondary calcite. The feldspars range from 2^{mm} in length down to minute microlites. The larger feldspars are commonly converted to calcite, which while it indicates their basic character, also prevents their accurate determination. Those which could be measured by the Michel-Lévy method proved to be andesine with formula Ab_1An_1 , hence more acid than the feldspars of the augite andesine. They contain glass inclusions, are zonally built with an occasional unaltered outer border, and are twinned according to the Carlsbad and albite laws but with very irregular intergrowths of the parts.

Hornblende is the only important ferro-magnesian mineral present and occurs, as the feldspars, both as large basal sections and long laths often with good crystal outline and also as shreds in the groundmass. The larger pieces are rarely in a good state of preservation, but occur with ragged edges and show resorption phenomena. The crystal is eaten into and part of the interior converted into magnetite with a few augite grains. Some crystals have been almost entirely replaced by calcite and magnetite, and others are represented by a ghost-like outline of magnetite dust. Commonly the hornblende is now changed to a green micaceous material, perhaps a variety

of chlorite, with parallel extinction and a pleochroism, c = white green, a = brown green. At times the former crystal is striped across with alternating bands of green and white in the direction of the cleavage cracks. Some of the crystals classed as hornblende are so altered that it is impossible to say that they may not be augite.

The groundmass is formed of small, stringy, ragged feldspars and varies in different slides from trachytic or pilotaxitic, with possibly a little glass, to a type formerly quite glassy and showing devitrified areas with incipient micropoikilitic structure. The feldspar microlites could not be accurately determined, but their average extinction indicates a variety as acid as oligoclase-andesine, and if strict nomenclature were to be considered, the rock would be classed as a trachyte-andesite.

Andesites of Southern Mapleton.—These occur in several localities and are either identical with, or present only minor variations from, the Edmund's Hill and Hobart's Hill masses. The rock which outcrops in the road two miles east of Mapleton village has the most glassy groundmass of all the andesites, and its devitrified areas have the micropoikilitic structure the best developed. Two outcrops show a type much lighter in color with much secondary and some original quartz, giving the rock a dacite facies. The other sections examined are of the typical augite-andesite or hornblende-andesite of this region, and require no detailed description.

Andesites of Castle Hill—Macroscopic description.—The rocks at this place do not have the character of lavas which have formed thick flows, but suggest rather the surface of a flow and are commonly amygdaloidal, or even slightly brecciated and ashy, and associated with them is an abundance of true volcanic ash with lapilli. The rock exposed at the south-east base of the hill is striking in its field appearance. Black, rusty-looking, spheroidal or elliptical masses of lava, one to two feet in diameter, first attract the attention as they lie loosely strewn over the surface. The solid ledge itself is seen to be composed of these forms, which have their outlines well displayed by weathering. These sack-like or pillow-shaped masses are plainly amygdaloidal on the surface, but usually much denser in the interior and are cemented together by a coarse breccia of rough tabular, spheroidal, or irregular jagged fragments of glassy material and igneous rock of similar composition to the spheres. In some places, noticeably on McDonald's hill to the south of Castle Hill proper, this structure assumes the form of a conglomerate of small amygdaloidal spheres six inches and less in diameter, closely cemented together with angular pebbles of andesite and other igneous

rocks. Similar structures have been described from California,* and from Scotland† and elsewhere. As noticed by Geikie, some basic lavas, e. g., the basalt at Acicastello in Sicily,‡ on flowing into water or a watery silt, assumes a remarkable spheroidal or pillow-shaped structure, "the spheroids being sometimes pressed into shapes like piles of sacks." This may be the explanation in the present case. Another interpretation is that the structure represents the ropy rolling surface at the front of a lava flow. On a fresh surface the rock is dark bluish-gray, uniform in texture or with a rare feldspar phenocryst. While this appears to be the most typical of the textures, it is usual to find vesicles now filled with calcite and fragments of volcanic debris large enough to constitute a conspicuous feature in the hand specimen. In weathering, the amygdaloidal parts go first and leave the more dense igneous and glassy pebbles exposed as a very rough surface.

Microscopic description.—Sections were cut from the densest material and also from that with macroscopic inclusions, and when examined with the microscope showed no difference except in size of vesicular areas and in method of alteration. Feldspar microlites make up the rock, parts of which are developed as areas of vesicular lava. The vesicles range in diameter from 2^{mm} to microscopic dots and are rudely oval in outline. The large ones are merely the larger part of a rounded area of vesicular glassy lava, containing a few feldspar threads like the body of the rock. Sometimes instead of one vesicle, filled with calcite, the same space will be occupied by a group of them, or the concave inner border of the large one may indicate its formation from several smaller ones. Some glassy oval areas occur with vesicles visible only under the highest powers. All these variations are doubtless caused by the fact that different sections of similar vesicular areas are exposed in the preparation of the slide. The only feldspar phenocryst seen in the sections is rounded in outline, has albite and pericline twinning, and is badly altered to calcite. Its extinction-angle indicates albite or andesine, and from the fact that phenocrysts are usually more basic than the components of the groundmass is referred to andesine. No ferro-magnesian mineral is present, but the numerous patches of chlorite and the fact that augite occurs in similar rock in the immediate neighborhood points to the former presence of pyroxene. Besides chlorite, there are present as secondary products calcite, a few epidote grains, and abundant iron ore. One slide is sprinkled full of stringy

* Ransome: Bull. Depart. Geol. Univ. of California, vol. i, p. 106. Fairbanks: Bull. Depart. Geol. Univ. Cal., vol. ii, p. 40.

† Geikie: Ancient Volcanoes of Gt. Britain, vol. i, p. 193.

‡ Johnston-Lavis: South Italian Volcanoes, p. 41.

black iron ore in long threads or lines of partly connected dots which are arranged to form barbed arrows or network of fibers which cross at angles of 60° and 90° , thus imitating the sagenite structure of rutile.

The groundmass is of long, stringy, narrow, frayed out microlites of feldspar with trachytic structure. Measurements of many laths gave practically a parallel extinction, thus indicating oligoclase. Expansion structure is developed where the vesicular areas are large enough to affect the orientation of the minute laths constituting the main body of the rock.

Andesite Ash Beds.—Beds of volcanic ash of an andesite character are represented in the region covered by this report. They are particularly abundant about Castle Hill and will be discussed in another place.

ART. XLIV.—*On a new mode of occurrence of Ruby in North Carolina* ;* by J. W. JUDD and W. E. HIDDEN. With Crystallographic Notes by J. H. PRATT.

PARTS of the State of North Carolina, with adjoining areas in South Carolina and Georgia, have long been known to mineralogists and geologists as among the most interesting of corundum localities; and the researches of the late Dr. Genth, Col. Joseph Willcox, Mr. J. Volney Lewis and many other authors have done much to make clear the mode of occurrence and associations of corundum in this area and in the great corundiferous belt stretching along the line of the Appalachian crystalline area from Alabama in the south to Maine in the north. Quite recently Dr. J. H. Pratt has published a very interesting and admirable discussion of "The origin of the Corundum associated with the Peridotites of North Carolina."†

But of the existence in any part of this area, or indeed in any part of the continent of America, of the red transparent variety of the mineral, to which the term Ruby is properly restricted, there appears to have been no knowledge till about 15 years ago (1884). Nor has there been, as yet, any notice published of the discovery in any scientific journal or magazine, unless we except the brief mention made in the Annual Statistical volume entitled Mineral Resources of the United States, published under the auspices of the U. S. Geological Survey.‡

Some few additional notes upon this interesting occurrence have been published, including press notices, but nothing of a strictly scientific character. We may state that one of us has during the past five years frequently visited the scene of this discovery, and that from time to time we have conjointly examined many of the cut specimens and natural crystals of the rubies from the Cowee district of North Carolina, and that in our opinion their beauty and color appear to be in no way inferior to those from the Mogok district of Burma.

As the material in which these rubies were found appeared so strikingly similar to the alluvium and gravel in which the Burma rubies are obtained, it at one time seemed highly probable that when the thick masses of superficial and detrital material could be sunk through, the rock in which the rubies would be found *in situ* would prove to be a limestone like

* From advance sheets of the Mineralogical Magazine and Journal of the Mineralogical Society, vol. xii, No. 56 (October, 1899).

† This Journal, IV, vol. vi, 1898, p. 49.

‡ 15th Annual Report, 1893-94, U. S. Geol. Survey, volume on Mineral Resources of the United States, Washington, 1894, p. 693; *ibid.*, 16th Annual Report, part iv, p. 599; *ibid.*, 17th Annual Report, part iii, p. 905.

that of Burma. This expectation was strengthened by the finding in the gravels of corundum crystals of similar form, with almost precisely the same association of minerals as occurs in Burma.

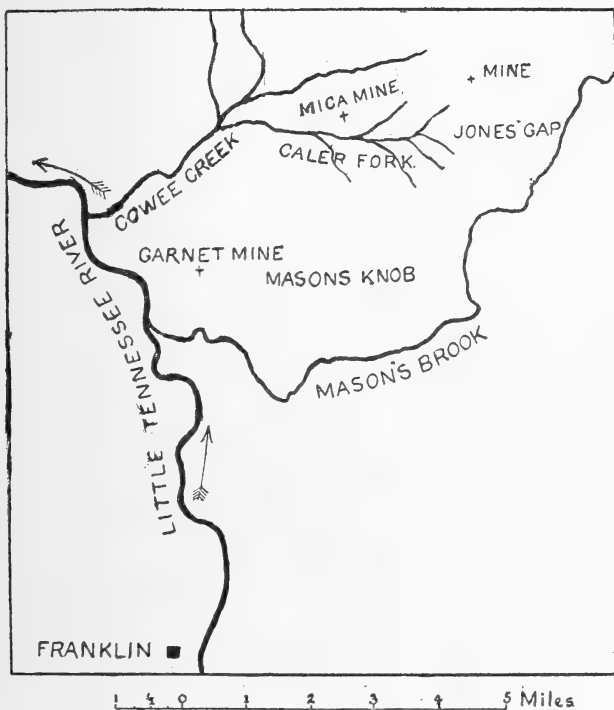


FIG. 1. Sketch map of the district in which Ruby and Rhodolite are found.

The district in which these interesting discoveries have been made is situated in the State of North Carolina and in the County of Macon, rather more than 20 miles from the borders of Georgia. Some five or six miles below the town of Franklin the Little Tennessee River receives on its right or eastern side two affluents, the Cowee Creek with its tributary the Caler Fork, and the Mason Branch. It is the tract between these two brooks, some 10 square miles in area, which has proved to be of such exceptional mineralogical interest, and has yielded a very large number of remarkable species and varieties of minerals.

The bottoms of the valleys of this mountain district are about 2,500 feet above the sea-level, and the various hills

("knobs") in and immediately around it rise to the height of from 3,000 to 3,500 feet; but at no great distance to the west there occurs much higher ground (the Nantahaleh Mountains) up to 5,000 and 5,500 feet.

In 1896 the district was visited and examined by Mr. C. Barrington Brown, who had made the examination for the British Government of the well-known ruby district of Mogok in Burma. He found that the country was one of gneissose rocks, the gneiss often containing garnets and corundum,* not of gem quality, and that this mass of gneissose rocks is probably traversed, like that of Burma, by great dikes of pegmatite and more basic rocks, for blocks of these materials are abundantly scattered through the gravels of the district.

Garnets are so abundant in some of the rocks of the district that mines have been opened to work the rocks for abrasive materials. In some of the pegmatites the crystals of muscovite are so well developed that several "mica mines" have been opened. There are other mines which have been worked for copper with some prospects of success; while, as we shall see in the sequel, gold, monazite, and sperrylite (the rare arsenide of platinum) have been obtained in the alluvial deposits which are so extensively present in this region.

Although only a few miles away from Corundum Hill, Buck Creek, Ellijay, and other famous corundum localities, where, as shown by Lewis, Pratt, and other authors, corundum is found in the intrusive dunites, near their junction with the crystalline schists of the district, *no* olivine rocks, or serpentines derived from them, have been found in the immediate neighborhood of the new ruby locality.

Neither have limestone rocks been found in close proximity to the alluvia containing these fine rubies. In fact, the nearest point at which any limestone bands have been found is about eight miles away. Here the bands consist of a "calciphyre," not unlike some of those found in Burma, and, like them, containing many silicates, such as wollastonite, scapolite, pyroxenes, hornblendes, biotite, etc., with graphite, pyrrhotite, and many other minerals.

When the alluvium and the gravels below them (the latter being from 2 to 10 feet in thickness) are penetrated, they are often found to rest on a soft rock known to American petrologists as "saprolite," which is the result of the weathering in place of basic silicate rocks. This "saprolitic" rock can often be pierced to considerable depths, without the undecomposed rocks from which it has been derived being reached.

* The corundum in these gneissose rocks usually occurs in long hexagonal prisms with basal planes, but no other forms, and the mineral nearly always exhibits purplish tints.

Washing and microscopic examination of the saprolitic material shows that it is largely made up of scales of various hydrous silicates, among which damourite and other hydrous micas, with margarites and other clintonites, are very conspicuous. The unaltered minerals present consist of fibrolite, staurolite, and some other silicates, with menaccanite, rutile, monazite, spinel, and considerable quantities of garnet (including the rhodolite variety) and corundum (of various shapes and tints), and minute quantities of gold and sperrylite.

The trial shafts and gravel-washing operations which have been undertaken in this district, with a view to discover the extent and nature of the valuable minerals, have shown that at depths of 35 feet and upwards the saprolitic rock includes fragments, and is seen to pass into various basic rocks. These include hornblende-eclogite (garnet-amphibolite of some authors), amphibolite, and a basic hornblendic gneiss containing labradorite and perhaps anorthite. The full description of these rocks is deferred until the exploration now going on shall have more fully displayed their relations in the field, and have enabled more satisfactory and less altered specimens to be obtained. It is as yet uncertain whether these rocks occur as dikes or as alternating interfoliated masses in the crystalline series.

The great band of basic and garnet-bearing rocks, in the decomposed materials derived from which are found the rubies, is traversed by a remarkable series of slickensides. Four parallel slides have been exposed at one place in the workings, the direction being generally N. 75° E. Continuous slickensides of 70 feet in length, and of unknown depth, can be seen, and, with some interruptions, they can be traced for several hundreds of feet east and west. It is probably the breaking up of these rock-masses by faulting, leading to the ready influx of water (which so readily attacks the basic silicates of which the rock is composed), that has led to their reduction to the saprolitic condition.

Scattered through the saprolitic material are nuclei of eclogite and amphibolite, which have to some extent escaped disintegration, and in the center of the mass lenticles of pure hornblende rock are found. In one place one of these lenticles of hornblende rock is nearly a rod in width, and in nearly all cases the saprolite adjoining these lenticles of hornblende rock is seen to contain, very abundantly, either corundum or more commonly the pseudomorphs after corundum.

The corundum occurring in these rocks varies in color from ruby-red through various shades of pink to white and nearly colorless varieties. Many of the red crystals exhibit the beautiful so-called pigeon's-blood tint, which is so much admired in

the gems from Burma, and the colors seen in the Cowee Creek stones with the dichroscope are almost identical with those exhibited by the stones from Burma. As at Mogok, Sagyin, and other Burmese localities, the rubies of very fine tint are mingled with others of lighter or darker shades, and with varieties which exhibit more or less of a purplish tint mingled with the red.

The Cowee Creek rubies very frequently contain inclusions of various kinds. Sometimes these are extremely minute ("silk" of jewellers), and give rise to a cloudiness ("sheen") in the polished gems; at other times minute reniform masses of clear red rutile and black menaccanite occur, and mar their beauty. The included crystals of garnet, to be hereafter more particularly noticed, do not greatly destroy the transparency or impair the fine character of the stones. Some specimens have been found, however, from which gems of fair size could be cut, quite free from inclusions and of fine color and transparency.

The clearest crystals of the Cowee Creek rubies nearly always show the tabular habit which Lagorio regards as characteristic of the varieties of corundum that have separated from an igneous magma. Indeed, so common is this form, that any long prismatic crystals found with them may be suspected of having been derived from the surrounding gneisses, in which such forms occur sometimes abundantly. The most common combination of forms is that shown in the accompanying drawing, which has been made by Professor S. L. Penfield, of the Sheffield Scientific School, Yale University.

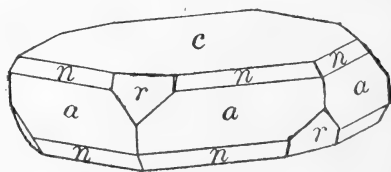


Fig. 2. Common form of Corundum Crystals at Cowee Creek.

In an appendix to this paper Dr. Pratt has drawn and described some of the chief types of corundum crystals obtained in the Cowee district, and it will be found interesting to compare these with the combinations of forms which the same author has described as occurring at Yogo Gulch, Montana,* and which Dr. Max Bauer has described from Burma.†

* This Journal, IV, vol. iv, 1897, pp. 424-428.

† Neues Jahrb. für Min., etc., 1896, Bd. II. pp. 197-238.

The corundum crystals, whether ruby-red or pink in color, occur in "nests" and "bands," and also in what appear to have once been empty spaces in the rocks, either amphibolite, or eclogite, or hornblendic gneiss. The spaces, when the corundum is pale-colored, appear to have been filled up with feldspathic material; but when the corundum is of ruby-red color, the surrounding space is filled up with chloritic material.

Corundum is not, however, confined wholly to these bands, which were once druse-like cavities in the rock, but it often happens that the mineral, sometimes red and transparent, is found in the midst of the rock.

One respect in which the corundum of Cowee Creek resembles that of Burma is in the readiness with which it seems to have undergone pseudomorphous change by hydration followed by combination of the resulting diasporite with surrounding silicates. The pseudomorphous material often retains the shape and occupies the place where crystals of corundum were originally firmly embedded in the hard matrix. Often only a thin flake of corundum remains in the midst of a mass of alteration products to tell the character and color of what was once a large crystal.

It is surprising to see the positive evidence of the former existence of hundreds of pounds weight of ruby and other varieties of corundum, where, to-day, only a few ounces of fragments or flakes remain.

The most notable of the minerals associated with the rubies and other forms of corundum at Cowee Creek is garnet, and this garnet is remarkable for its color and beauty as a gemstone. The color is unlike that either of pyrope or almandine, and lacks that depth and intensity which usually makes garnets such dark-looking stones, especially by artificial light. These garnets, on the contrary, have a peculiar and very beautiful tint, combined with a transparency and brilliancy which is more striking in artificial light than in ordinary daylight. From the resemblance of its color (a pale rosy tint inclining to purple) to that of certain roses and rhododendrons, this variety of garnet has received the name of "rhodolite."*

The rhodolite usually occurs in water-worn fragments, mixed with corundum and the other minerals found in the "saprolitic" rock and in the gravels of the district. Only minute crystals, occurring as inclusions, have as yet been found, and these are sometimes rhombic-dodecahedrons and at other times trapezohedrons (icositetrahedrons). The garnets show the same tendency to alteration as the corundum, and pseudomorphs of the mineral abound, as is the case in Burma.

* The rhodolite of the Cowee Creek and Mason's Branch district has been recently carefully studied by Dr. Pratt in conjunction with one of us.

The association of rubies and rhodolite in this district is not only proved by their constant occurrence together in the saprolitic material and in the gravels, but we found indisputable evidence that the garnets have crystallized first and that the corundum has solidified afterwards and has enclosed the garnets partially or entirely in its crystals. Some of the ruby crystals bear impressions, of which a mould can be taken in wax, and these impressions give with a goniometer the angles of the rhombic-dodecahedron or the trapezohedron. In some cases clear crystals of ruby corundum have been broken open, and minute garnets actually taken out of the middle of them. In other cases fractured surfaces of the basic rocks show corundum surrounding and enclosing garnet crystals, while in other cases cut gems of ruby can be seen to have in their midst a garnet crystal.

So far as our experience goes, this enclosure of garnet by corundum is peculiar to this special Cowee district, and serves to distinguish the corundum found in it from that occurring in any of the tracts where the mineral occurs in peridotites (dunite, etc.), or at the junction of peridotites with the crystalline schists.

This remarkable association of garnet and corundum is well illustrated by a drawing (fig. 3) made upon the spot by one of us from a specimen.

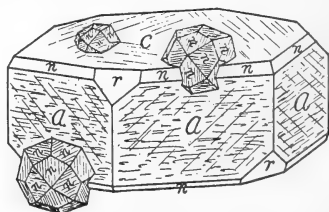


FIG. 3. Corundum enclosing Crystals of Garnet.

Specimens are occasionally found in the district which appear to be pseudomorphs of quartz after dodecahedral garnets.

Spinel, which is so constantly associated with the corundum (ruby) of Burma, is rare in the American locality. The fine red spinels, so similar in tint to the rubies themselves, and so conspicuous in the Burma localities, appear to be entirely wanting in the North Carolina area. Three varieties of spinel, namely, picotite, gahnite, and chromite (the last being rare), have been found both in the alluvial deposits and *in situ* in the basic rocks.

Of minerals specially characteristic of materials formed by contact metamorphism, the following have been found: Sillimanite (fibrolite), cyanite, staurolite (often very clear and gem-like in character), and cordierite or iolite (colorless and without dichroism).

The chief ferro-magnesian silicates are hornblende (a variety rich in soda) and bronzite (in clear transparent masses suitable for gems).

Among the accompanying minerals are: zircon (with the variety cyrtolite), monazite (the macroscopic brown and green varieties appear to be rare, but a minute brilliant yellow granular variety with only 0.03 per cent of thorium abounds), rutile and menaccanite.

Among metallic minerals the chief are pyrite, chalcopyrite, nickeliferous pyrrhotite, blende, sperrylite, and gold.*

Conclusions.

Corundum has now been shown to occur in North Carolina and the adjoining States in three different forms:

(1) In the ordinary crystalline schists of the district, long prismatic crystals, usually of gray, pink and blue tints, occur.

(2) In the peridotites (dunites, etc.), intrusive in the crystalline schists, and especially in and near the zones of contact, crystals, some of very great size and of great variety of color, but seldom or never clear and translucent, are found.

(3) In certain garnet-bearing basic rocks at Cowee Creek, small tabular and short prismatic crystals are abundant, and these very frequently exhibit the transparency and color of the true ruby.

Dr. Pratt, in his recent discussion on the second of these modes of occurrence of corundum, has shown grounds for concluding that the alumina of the corundum was in these cases originally dissolved in the fused basic magma of the peridotites, and that crystals of corundum separated from that magma in the manner which has been illustrated by the interesting experiments of Morozewicz.†

The tabular form of the crystals of corundum has been shown by Lagorio‡ in his well-known memoir on the subject to be characteristic of corundum found in igneous rocks. And this conclusion has been supported by the researches of Prof. L. V. Pirsson and Dr. Pratt.§

If we compare the forms figured by Dr. Pratt in the appendix to this paper with those described by him from Yogo Gulch, the resemblance will be seen to be very striking. But

* For fuller details concerning these accompanying minerals with analyses consult a paper "On the Associated Minerals of Rhodolite," by W. E. Hidden and J. H. Pratt, this Journal, IV, vol. vi, 1898, pp. 463-468.

† Zeitschr. Kryst., vol. xxiv, 1895, p. 281, and Tscherm. Min. und Petr. Mitt. vol. xviii, 1898, pp. 1-90, 105-240.

‡ Zeitschr. Kryst., vol. xxiv, 1895, p. 285.

§ "Corundum-bearing Rock from Yogo Gulch, Montana," by L. V. Pirsson, this Journal, IV, vol. iv, 1897, p. 421; "Crystallography of the Montana Sapphires," by J. H. Pratt, *ibid.*, p. 424.

it may at first sight appear that it is impossible to ascribe an igneous origin to corundum enclosing a mineral with so much lower a fusing point as that of garnet.

A little consideration will, however, show that this objection has little validity. The temperature at which alumina is dissolved in a mixture of silicates has no necessary connection with the fusing point of alumina itself. That the magma from which these basic rocks consolidated was fluid at a temperature lower than the fusing point of the garnets, or at all events that the rock was in a state of aqueo-igneous fusion at a lower temperature, is evidenced by the condition of the beautifully crystallized garnets scattered through the basic rocks. At such temperatures, according to the experiments of Morozewicz, alumina may be largely dissolved in the basic fluid magma, and may slowly crystallize out from it. In this way we may conceive of the garnets being enclosed in a later formed corundum.

There are many points of resemblance between the association of minerals and the forms of crystallization of the Cowee Creek rubies and those of Burma. This will become apparent if we compare the figures now published with those given by Prof. Max Bauer of the Burma rubies.*

In considering the association of minerals described by Prof. Max Bauer in his paper, it should be remembered that the material on which that author worked came almost entirely from Sagyin, while those described by Mr. Barrington Brown and one of us were derived from the Mogok district, nearly 60 miles away. There is reason for concluding that the association of minerals in these two districts of Burma present some interesting points of difference.

Although, at first sight, the matrix of the Burma rubies (a crystalline limestone) may seem so different from that of the rubies of Cowee Creek (an amphibolite with garnets, and sometimes with a basic feldspar) yet a connection may still be shown to exist between the two cases. One of us has brought forward evidence to show† that the limestone of Burma has been formed by the slow alteration of a lime feldspar. Whether the corundum pre-existed in the highly-basic feldspathic rock, however, or was formed at a later stage, there is no positive evidence to show. But the idea of its existence in the silicate rock originally is supported by the wonderfully corroded state of the corundum crystals.

The magma giving rise to pyroxene gneisses and granulites of Burma may not have differed greatly in composition from that giving rise to the amphibolites, eclogites, and basic gneiss

* Neues Jahrb. Min., etc., 1896, Bd. ii, Taf. vii.

† Phil. Trans., vol. clxxxviii, 1896, pp. 151-228.

of North Carolina; and, in either case, corundum may have been formed by the separation of dissolved alumina. The great promise which is held out by the fine color and quality of many of the ruby crystals from this new locality would seem to warrant a continuance of the prospecting work lately inaugurated there, and it is to be hoped that the interesting problem of *the true origin of these rubies* may be definitely settled when the explorations on Cowee-Creek shall have furnished fuller data and more conclusive evidence concerning the primary condition of the associated minerals and the nature and relations of the rocks of the district.

On the Crystallography of the Rubies from Macon County, North Carolina; by J. H. Pratt.

The ruby crystals from the Cowee Valley, Macon County, North Carolina, show a very wide variation in their development. Although many of the crystals are so striated that no crystallographic measurements were possible on the reflecting goniometer, the faces were readily identified by means of the contact goniometer. On some of the crystals the faces were bright and smooth, making them well adapted for measurement on the reflecting goniometer. The following references are to the figures on p. 380.

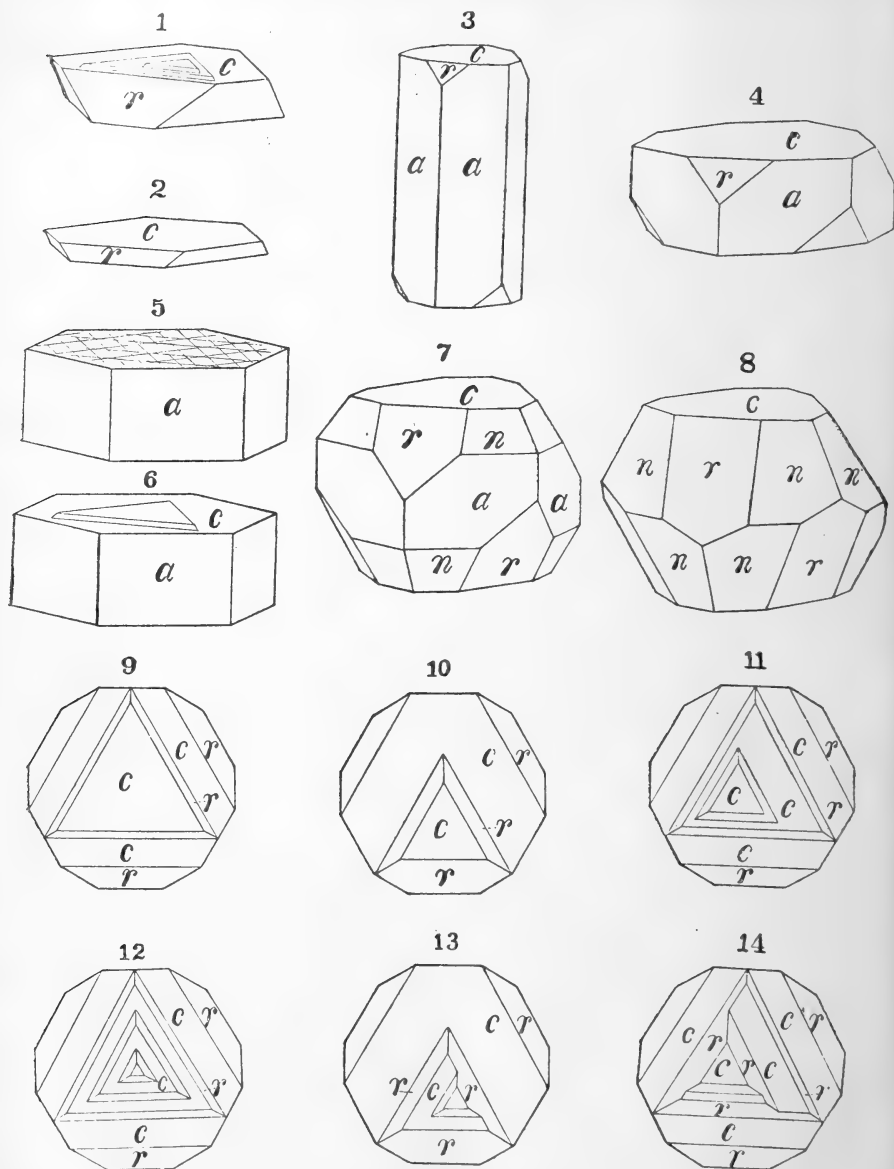
Among the crystals examined there were two common habits noticed, one, as shown in figs. 1 and 2, which is a combination of the base $c(0001)$ and the unit rhombohedron $(10\bar{1}1)$; the other, represented by figs. 3 to 6, where the prism $a(11\bar{2}0)$ is very prominently developed. The rhombohedral crystals vary from those where the base is largely developed, having a diameter of 12^{mm} , while the rhombohedron is only 1.5^{mm} , to some (fig. 1) which have the base and rhombohedron more equally developed. The majority of these crystals have, however, the base more largely developed, thus giving the crystals a flat tabular appearance. This rhombohedral development is very similar to that of the sapphires from Yogo Gulch, Montana, described by the author.*

On some of the prismatic crystals the prism reaches a length of nearly 15^{mm} in the direction of the c -axis, and has the rhombohedron but slightly developed (fig. 3), while on others the prism is very short and the rhombohedron sometimes is wanting, as represented in figs. 4 and 5.

Another habit of these crystals is shown in figs. 7 and 8. There the pyramid $n(22\bar{4}3)$ is well developed. This face was identified by means of the contact goniometer, the measurements approximating closely to the calculated angles. The

* This Journal, vol. iv, 1897, p. 424.

usual form of these crystals is shown in fig. 7, where the faces $c(0001)$, $a(11\bar{2}0)$, $r(10\bar{1}1)$ and $n(22\bar{4}3)$ are nearly equally devel.



oped. On some of the crystals the prism is very prominent, being 8^{mm} in length in the direction of the c -axis, while the pyramid is only 1.5^{mm} . On others the pyramid is only very

slightly developed. A few crystals were examined which showed only the presence of the base, the rhombohedron and the pyramid, as represented in fig. 8. The crystals, measuring up to 7^{mm} in diameter, were doubly terminated and nearly perfect in their development.

The crystals represented by fig. 7 are similar to those described by Max Bäuer* from the Burma district, and are almost identical in form with a sapphire crystal figured by the author, from Emerald Bar, Cañon Ferry, Magher County, Montana.

Although both the basal and rhombohedral planes are very often striated, it is only on the basal planes that these are sharp and distinct and can be measured. The striations are parallel to the three intersections of the base c with the rhombohedron r , as shown in fig. 5.

A very common development that was noticed in nearly all the flat rhombohedral crystals, and on many of the prismatic crystals, is a repeated growth on the basal plane of the rhombohedron $r(10\bar{1}1)$ and the base $c(0001)$, as represented in figs. 1 and 6.

To better illustrate the variation in these growths, a series of figures (9 to 14) have been drawn in basal projection. In figs. 9 and 10, which represent the more common development of these repeated growths, there is but one secondary rhombohedron and base, which sometimes has one of its rhombohedron faces a continuation of one of the rhombohedron faces of the crystal. Figs. 11 and 12 represent repeated growths, the faces of which are separate and distinct from each other and from the faces of the main crystal. In the crystals represented by fig. 12, when the secondary growths are but slightly developed the basal plane of the crystal has the appearance of being striated with triangular markings. In figs. 13 and 14 there are represented a series of growths where a number of the rhombohedral faces coincide.

Some of the pyramidal crystals (figs. 7 and 8) also showed the development of the secondary growth of rhombohedron and base.

The thickness of the rhombohedron of the secondary growth varies from those that are so thin that they appear like striations to some that are 2^{mm} thick.

This same style of development has been described by Bauer† as occurring in the Burma rubies, and it has also been described by the author‡ as occurring on the Montana sapphires.

A few crystals were observed on which there was a secondary growth parallel to the prism (11 $\bar{2}$ 0).

* Neues Jahrb Min., 1896, ii, 197.

† Loc. cit., p. 209.

‡ This Journal, vol. iv, 1897, p. 424.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Solidification of Hydrogen.*—Toward the end of 1898, as soon as DEWAR had obtained two or three hundred cubic centimeters of liquid hydrogen, he attempted its solidification by boiling it under reduced pressure; but without result, no solid hydrogen being produced, even when the ebullition was effected under a pressure as low as ten millimeters. Subsequently he observed that a trifling leakage of air, such as it was almost impossible to prevent at this low temperature, produced, when the pressure was reduced below 60^{mm} a remarkable effect, causing a sudden solidification in the form of a gelatinous froth. At first he thought this was a sponge of solid air containing liquid hydrogen. But as it evaporated completely at this low pressure without leaving more than a trace of solid air, he concluded that it must be solid hydrogen. In confirmation of this view, he found that on increasing the pressure, and consequently the temperature, the solid melted when the pressure attained about 55^{mm}. Using a graduated tube attached to a closed balloon of about a liter capacity filled with pure hydrogen gas, he found that when this tube was immersed in boiling hydrogen, liquid hydrogen accumulated in it till the outside pressure reached 30 or 40^{mm} and the outside liquid became a solid froth. On inverting the apparatus, no flow could be observed along the tube; and in a strong light, the material in the lower part of this tube could be seen as a transparent ice. This solid hydrogen melted at a pressure of 55^{mm}. The temperature of fusion, determined with a hydrogen thermometer, was found to be about 16° absolute, under a pressure of 35^{mm}, theory indicating 16.7°. So that the practical limit of temperature which can be reached by the evaporation of solid hydrogen is 14° or 15° absolute. It is to be noted that the critical temperature of hydrogen being 30° to 32° absolute, its fusing point is one-half of this, i. e., 16°. The frothy appearance of the solid, as ordinarily produced, is due to the low density of the liquid and its rapid evaporation. These results would seem to destroy the hypothesis of the metallic character of hydrogen and to require its classification among the non-metallic elements.—*C. R.*, cxxix, 451-454, September, 1899. G. F. B.

2. *On Hydrazoic acid and its salts.*—Further researches have been made by CURTIUS and RISSOM upon hydrazoic acid (HN₃) and its salts. The acid itself was prepared by distilling with sulphuric acid the lead nitride which is obtained as a by-product in the preparation of ammonium nitride. The aqueous solution thus obtained is quite permanent even on heating; but on boiling with strong acids it is decomposed with the evolution of gas. The ammonium nitride (NH₄N₃) is the most interesting of the

salts described. It is very volatile and explodes readily with great violence. But notwithstanding this the authors succeeded in determining its vapor density. The other salts arrange themselves according to their solubilities between the chloride and the bromide. In aqueous solution they behave as would be expected from the feebleness of the free acid. In the case of weaker bases, particularly alumina and iron oxide, strong hydrolysis takes place; so that in experiments made to form aluminum salts by double decomposition, alumina is precipitated. The non-dissociated part of the iron salts is colored deep red, like the acetates; but this substance is rapidly decomposed with the deposition of iron oxide.—*J. pr. Ch.*, lviii, 216-309, 1898; *Zeitschr. Phys. Chem.*, xxix, 174, May, 1899.

G. F. B.

3. *On Argon and its Combinations.*—The earlier investigations of BERTHELOT to determine the possibility of causing argon to enter into combination with other bodies, have now been repeated under improved conditions. The argon was obtained from Ramsay, and after purification amounted to 455°. As in the previous experiments the argon, mixed with the substance to be acted upon, in either the gaseous, the liquid or the solid state, was placed in a silent discharge tube and submitted to the action of the electric spark from an induction coil giving discharges of 6 or 8^{mm}. Only from 5 to 10° of argon was used in each experiment, the substance added being gaseous, liquid or solid at pleasure. The first experiments were made with bodies of the fatty series, such as ethylene, aldehyde, acetone, petroleum ether, propionitrile and amylamine. No absorption of argon was observable. In the second set of experiments, bodies of the benzene series were tested, such as benzene, toluene, phenol, aniline and benzonitrile. A characteristic absorption of argon was observed, accompanied with a greenish luminescence visible in full daylight, and giving in its spectrum the lines of argon, of mercury, of carbon and of hydrogen; it being especially bright with benzene, toluene, benzonitrile and anisol. The author regards this result as due to the formation of a special substance phenylmercurargon, having only a very small vapor pressure. The action is in marked contrast with that on the fatty series. In a third set of experiments, cyclic compounds such as furfural, thiophene, pyrrol and pyridine, were employed. The absorption of argon was much less, in some cases not even perceptible, and the light was feeble. Special experiments were then made with benzene and with carbon disulphide. In the case of benzene, the absorption of argon varied from 3 per cent. to 14 per cent, depending upon the relative amount of the two substances present and the time of exposure, the last result being obtained with equal volumes of argon and liquid benzene, the latter therefore in large excess. Benzene was found to dissolve 18 per cent of its volume of argon, carbon disulphide 6 per cent. The compound formed by argon with carbon disulphide is reddish in color and is solid. The absorption varied from 6 per cent. after six hours, to 7 after twenty

hours. By increasing the current pressure and so the temperature, the absorption was diminished. When hydrogen was added to the mixture, 10 per cent of argon was absorbed in 24 hours, all the hydrogen having disappeared. When benzene was thus added, the absorption was 9 per cent. It hence appears that to fix a molecule of argon (A_2) 34 molecules of carbon disulphide are required $(CS_2)_{34}$. In all cases a solid amorphous, reddish polymerized substance is formed; the polymerization of the bisulphide and the combination of hydrogen, of nitrogen or of argon proceeding simultaneously. The results obtained lead the author to suspect the existence of metallic argonides in those minerals which evolve argon under the action of acids, or even of hydrogen argonide. In a subsequent communication Berthelot gives the results of his experiments on the action of the electric discharge on argon mixed in one case with mercury-dimethyl, and in the other with mercury-diphenyl. No absorption took place in the first case, while in the second, owing to the production of phenylmercurargon, 6.5 per cent of argon was absorbed and the green luminescence was produced.—*C. R.*, cxxix, 71–84, 378–9, July, August, 1899.

G. F. B.

4. *On Mercury in the Colloidal Condition.*—By reducing mercurous nitrate with stannous nitrate, adding ammonium citrate solution and filtering through an earthenware filter, LOTTERMOSER has succeeded in preparing colloidal mercury, which after drying is obtained in the form of brilliant silver-like masses which dissolve in water giving a dark brown solution. If this colloidal mercury is treated with dilute chlorine water, mercurous chloride is obtained, also in the colloidal state. In the same way the bromide and the iodide can be procured as colloids. The colloidal iodide appears as a deep red solution from which the iodide is rapidly deposited.—*J. pr. Ch.*, lvii, 484–487, 1898; *Zeitschr. Phys. Chem.*, xxix, 174, May, 1899.

G. F. B.

5. *On Lithium-ammonium and Calcium-ammonium and the Amides of these Metals.*—It has been observed by MOISSAN that, like potassium and sodium, lithium and calcium dissolve in liquid ammonia with a blue color. But while the $NaNH_2$ decomposes at -20° and KNH_2 at -2° , into metal and ammonia, the lithium and calcium compounds are permanent at the ordinary pressure and temperature, the $LiNH_2$ remaining unchanged up to $+70^\circ$ and the $CaNH_2$ up to $+20^\circ$; these compounds evolving so much heat in their formation that in the case of the lithium this metal is fused. On spontaneous evaporation as much ammonia becomes solid as corresponds to the formula $Li(NH_2)_3$. About 70° , there is formed crystallized $Li(NH_2)_2$; but by diminishing the pressure, this compound decomposes into metallic lithium and ammonia. Calcium ammonium corresponds to the formula $Ca(NH_2)_4$. Both lithium and calcium ammonium ignite spontaneously in the air. When instead of liquid ammonia, methylamine is brought in contact with lithium at -20° , a blue liquid is formed having approximately the composition $Li(NH_2CH_3)_3$. On evaporation in vacuo,

metallic lithium remains besides a blue crystalline compound $\text{Li}(\text{NH}_2\text{CH}_3)$ or lithium monomethylammonium, the NH_2CH_3 pressure being less than one atmosphere.—*C. R.*, cxxvii, 685–693, 1898; *ib.*, cxxviii, 26–30, 1899; *Zeitschr. Phys. Chem.*, xxix, 738, 747, September, 1899. G. F. B.

6. *On the Action of Potassammonium and of Sodammonium on Sulphur, Selenium and Tellurium.*—The action of the metallic ammoniums upon sulphur, selenium and tellurium has been studied by HUGOT. The apparatus used consisted of two large parallel tubes of glass united by a smaller tube containing glass wool. The metal and the metalloid are placed in one branch of the tube, previously filled with ammonia gas. The two branches are then sealed and connected with a reservoir containing the liquid ammonia, which collects in one of these branches. The alkali-ammonium dissolves in the excess of liquid giving a reddish-brown solution, which reacts upon the sulphur, selenium or tellurium present, giving rise to a white powder insoluble in the liquid (if the metalloid is present in excess) and which has the composition Na_2S , Na_2Se , or Na_2Te , formed with sodium or K_2S , K_2Se or K_2Te , when potassium is used. They are soluble in water free of air and give a colorless solution. When, however, the metalloid is in excess, the mono-compound which is first formed dissolves, the liquid becomes brown or violet and very limpid. On evaporating it at -25° , with subsequent lowering of pressure, the excess of ammonia is removed and a brown crystalline mass is left having the composition K_2Se_4 or Na_2Se_4 for selenium and similar formulas for sulphur and tellurium. These substances are all crystalline, are soluble in water but not soluble in liquid ammonia. They absorb ammonia gas.—*C. R.*, cxxix, 299–302; 388–390, July, August, 1899. G. F. B.

7. *A Short History of the Progress of Scientific Chemistry in our own times*; by WILLIAM A. TILDEN, F.R.S., Professor of Chemistry in the Royal College of Science, London. 8vo, pp. x, 276. New York, 1899 (Longmans, Green & Co.).—This excellent little book of Professor Tilden's had its origin in a course of lectures to working men such as the professors in the Royal School of Mines and the Royal College of Science have delivered annually for the last five and thirty years. Among the subjects treated in its ten chapters are Matter and Energy, the Chemical Elements, Standardization and Classification of Atomic Weights, Origin of the ideas of Valency, Synthetical and Stereo-Chemistry and the Liquefaction of Gases. The facts have been carefully selected and are attractively presented. The book will be of great service to the chemical student as a valuable résumé of the recent progress of Chemical Science. G. F. B.

8. *Refraction of the X-rays.*—A renewed interest has been taken in this subject. It seemed to H. HAGA and C. H. WIND, that the investigations of Fomm, *Wied. Ann.*, lix, p. 350, 1896, appeared to open a way for the determination of a possible refraction. It was shown by P. G. Tiddens, *Beibl.*, xxi, p. 603, 1897, that the Fomm

bands were not produced by refraction. Haga and Wind set themselves to determine what causes the Fomm bands and whether there are refraction phenomena in the case of the X-rays. The Fomm bands or lines are maxima produced by a difference of illumination on a surface lighted through a slit, and the phenomenon was studied as early as 1866 by E. Mach, and the results were published in the Proceedings of the Vienna Academy of Sciences under the title "Ueber die Physiologische Wirkung räumlich-vertheilter Lichtreize." A study of this pseudo diffraction effect showed the authors that their earlier work on the wave nature of the Röntgen rays fell to the ground, and that previous investigations in which the distance between the Crookes tube and the sensitive plate was as much as 24 meters and the time of exposure 80 hours, and in which double-flowed plates and strengthening screens were used, are worthless. The authors, moreover, are convinced that the eventual wave length of the X-rays must be of far smaller value than has been supposed. New experiments were then undertaken to test the question whether there are true refraction effects with X-rays. The authors believe that such effects will be found and that the wave length of the rays lies under a tenth of $\mu\mu$.

C. H. Wind also discusses the question whether the refraction phenomena studied by Haga and himself are due to certain vibrations of the source of light 3000 times smaller than the time of vibration of yellow light, and that the emission of the X-ray system must be ascribed to a nature of vibration entirely different from that of ordinary light. He comes after an analytical discussion of this question to the conclusion that this conclusion is not justified (Wied. Ann., No. 8, 1899, pp. 884-901).

M. Maier has also investigated the question of the refraction of the X-rays and states that he has discovered interference phenomena which indicate the wave nature of these rays. He finds wave lengths 0.000015^{mm} in length. His experiments do not decide the question of the transversality of these waves, for no polarization phenomena were in evidence.—Wied. Ann., No. 8, 1899, pp. 903-916. J. T.

9. *Radio-active substances*.—E. DE HAËN has discovered two preparations of uranium earth which possess the property of exciting X-rays in a remarkable degree. Preparation A shows the phenomenon of the Becquerel rays; excites fluorescence of barium platinum-cyanide screens, even through substances opaque to light; acts upon photographic plates; makes air conducting for electricity, and has, moreover, the hitherto undiscovered property of being self-luminous. Preparation B proves to have in general the peculiarities of preparation A. The excitation of a screen is more intense, the self-lighting is much weaker.—Wied. Ann., No. 8, p. 902. J. T.

10. *Physikalische Zeitschrift*, No. 1-2, pp. 1-38, Leipzig (S. Hirzel).—Physicists will be interested in the appearance of the *Physikalische Zeitschrift*, of which the first number (1 and 2) was

issued on the 1st of October. This new periodical is to be conducted by Dr. E. Riecke and Dr. H. Th. Simon of Göttingen, aided by a considerable staff of co-workers, for the preparation of abstracts. It is to be issued in weekly numbers at a cost of 5 marks for three months. As a prompt means by which physicists may present the results of their work, it will doubtless prove of great value and contribute much to the progress of science. The portion devoted to abstracts and book notices also promises to be carefully and thoroughly conducted.

II. GEOLOGY AND NATURAL HISTORY.

1. *On Geological Time.*—The address of Sir ARCHIBALD GEIKIE, before the Geological Section of the British Association at the recent Dover meeting, was an able presentation of the profound problem of geological time. He opened with a historical summary of the successive phases of the discussion, beginning with the writings of Hutton, to whom modern geology owes so much. The conclusion of Hutton's philosophy is thus stated, "that the history of the earth occupied prolonged though indeterminate ages in its accomplishment." The Uniformitarian School, following, founded on the teachings of Hutton and Playfair, came to believe that an absolutely unlimited extent of time was at the disposal of geologists. In 1862, however, the discussion of the subject was first undertaken from the physical side, when Sir William Thomson (Lord Kelvin), in his paper on the secular cooling of the earth, announced the conclusion that the age of the earth must be more than 20 millions but less than 400 millions of years. Since that time the physical arguments have been restated and reargued by Lord Kelvin and others, the latest conclusion of the same physicist (Victoria Institute address of 1897, see this Journal, vii, 160), being that the age "was more than twenty and less than forty millions of years and probably much nearer twenty than forty."

This conclusion, however, has not been universally accepted by physicists, for example, Professor Perry in 1895 closed a discussion intended to show the uncertainty of the physical data upon which the estimate was based, by the remark: "It is to be observed that if we exclude everything but the arguments from mere physics the *probable* age of the earth is much less than any of the above estimates; but if paleontologists have good reasons for demanding much greater times, I see nothing from the physicist's point of view which denies them four times the greatest of the estimates."

After this historical summary, the writer goes on to protest vigorously against the ignoring of the evidence adduced by geologist and paleontologist which has often characterized the discussions of the physicist. He writes: "It is difficult satisfactorily to carry on a discussion in which your opponent entirely ignores your arguments, while you have given the fullest attention to his.

In the present instance, geologists have most carefully listened to all that has been brought forward from the physical side. Impressed by the force of the physical reasoning, they no longer believe that they can make any demands they may please on past time. They have been willing to accept Lord Kelvin's original estimate of 100 millions of years as the period within which the history of life upon the planet must be comprised ; while some of them have even sought in various ways to reduce that sum nearer to his lower limit. Yet there is undoubtedly a prevalent misgiving, whether in thus seeking to reconcile their requirements with the demands of the physicist they are not tying themselves down within limits of time which, on any theory of evolution, would have been insufficient for the development of the animal and vegetable kingdoms."

Going on to discuss the evidence as to the rate of change and intensity of action of geological changes in earlier geological times as compared with the more recent, he says: "They [geologists] have been unable to discover any indication that the rate of geological causation has ever, on the whole, greatly varied during the time which has elapsed since the deposition of the oldest stratified rocks. They do not assert that there has been no variation, that there have been no periods of greater activity, both hypogene and epigene. But they maintain that the demonstration of the existence of such periods has yet to be made. They most confidently affirm that whatever may have happened in the earliest ages, in the whole vast succession of sedimentary strata nothing has yet been detected which necessarily demands that more violent and rapid action which the physicists suppose to have been the order of nature during the past.

"So far as the potent effects of prolonged denudation permit us to judge, the latest mountain-upheavals were at least as stupendous as any of older date whereof the basal relics can yet be detected. They seem, indeed, to have been still more gigantic than those. It may be doubted, for example, whether among the vestiges that remain of Mesozoic or Palæozoic mountain-chains any instance can be found so colossal as those of Tertiary times, such as the Alps. No volcanic eruptions of the older geological periods can compare in extent or volume with those of Tertiary and recent date. The plication and dislocation of the terrestrial crust are proportionately as conspicuously displayed among the younger as among the older formations, though the latter, from their greater antiquity, have suffered during a longer time from the renewed disturbances of successive periods." And further: "It is thus abundantly manifest that even in the most ancient of the sedimentary registers of the earth's history, not only is there no evidence of colossal floods, tides and denudation, but there is incontrovertible proof of continuous orderly deposition such as may be witnessed to-day in any quarter of the globe. The same tale, with endless additional details, is told all through the stratified formations down to those which are in the course of accumulation at the present day."

A consideration of the paleontological evidence shows how strong an argument can be made on this side. He concludes: "Until, therefore, it can be shown that geologists and paleontologists have misinterpreted their records, they are surely well within their logical rights in claiming as much time for the history of this earth as the vast body of evidence accumulated by them demands. So far as I have been able to form an opinion, one hundred millions of years would suffice for that portion of the history which is registered in the stratified rocks of the crust. But if the paleontologists find such a period too narrow for their requirements, I can see no reason on the geological side why they should not be at liberty to enlarge it as far as they may find to be needful for the evolution of organized existence on the globe. As I have already remarked, it is not the length of time which interests us so much as the determination of the relative chronology of the events which were transacted within that time. As to the general succession of these events, there can be no dispute. We have traced its stages from the bottom of the oldest rocks up to the surface of the present continents and the floor of the present seas. We know that these stages have followed each other in orderly advance, and that geological time, whatever limits may be assigned to it, has sufficed for the passage of the long stately procession.

"We may, therefore, well leave the dispute about the age of the earth to the decision of the future. In so doing, however, I should be glad if we could carry away from it something of greater service to science than the consciousness of having striven our best in a barren controversy, wherein concession has all to be on one side and the selection of arguments entirely on the other. During these years of prolonged debate I have often been painfully conscious that in this subject, as in so many others throughout the geological domain, the want of accurate numerical data is a serious hindrance to the progress of our science. Heartily do I acknowledge that much has been done in the way of measurements and experiments for the purpose of providing a foundation for estimates and deductions. But infinitely more remains to be accomplished. The field of investigation is almost boundless, for there is hardly a department of geological dynamics over which it does not extend. The range of experimental geology must be widely enlarged, until every process susceptible of illustration or measurement by artificial means has been investigated. Field-observation needs to be supplemented where possible by instrumental determinations, so as to be made more precise and accurate, and more capable of furnishing reliable numerical statistics for practical as well as theoretical deductions."

The writer closes by an enumeration of some of the different lines of investigation which, if followed out, might be expected to lead to more definite knowledge in regard to this fundamental question, and suggests that the coming International Geological Congress to be held in Paris in 1900, might well organize a system of combined observations looking to this end.

2. *An Estimate of the Geological Age of the Earth*; by J. JOLY, University of Dublin.—The latest contribution to the subject ably argued by Sir Archibald Geikie at the meeting of the British Association (see above), is that by Professor J. Joly in a paper published in vol. vii of the *Scientific Transactions* of the Royal Dublin Society, September, 1899. In this interesting memoir the author discusses the geological age of the earth since the formation of the ocean, basing his calculations upon the time required to supply to it the amount of sodium now present in the water. He starts with the assumption of the Uniformitarian, that the processes now going on may be considered to have continued essentially as at present for the whole period in the past here concerned. The basis on which his argument is placed will be understood from the following paragraphs.

“In the method of approaching the question of the Age of the Earth advanced in this paper, the foregoing tenet* requires only acceptance in part—that part of it which refers to the removal of the land surface by *solution*. It has to be accepted as a preliminary step that this, on the whole, has been constant. Herein are involved a constancy, within certain fairly wide limits, of rainfall over the land areas; a constancy within fairly wide limits (which can roughly be defined) of the exposed land area, and a constancy in the nature and rate of solvent actions going on over the land surfaces. The grounds on which this amount of uniformity is accepted are given in this paper. One other tenet must be accepted, that the primeval ocean—that formed on first condensation of the water upon the land—did not contain the amount of dissolved sodium now entering so largely into its constitution. The grounds upon which this is claimed are also dealt with further on.

“How can these data be used to determine what may be termed the Epigene Age of the Earth? In the sea or in its deposits those elements are recognizable which enter also into the constituents of the solid part of the Earth’s crust. In the rivers these elements are also recognizable as being continually poured into the ocean. Very accurate estimates of the quantities of these elements in the ocean exist. The dissolved contents of many of the great rivers of the Earth and the mean composition and mean volume of the entire river discharge have been estimated.

“Now if any of the elements entering the ocean is not again withdrawn, but is, in a word, ‘trapped’ therein, re-appears as no extensive marine deposit, and is not laid down sensibly upon its floor; and if the amount of Uniformity already defined is accepted, evidently in the rate of annual accretion by the ocean from the rivers of this substance and the amount of it now in the ocean, the whole period since the beginning of its supply can be estimated.

*[That the rate of removal of the subærial land surface—by solution and transportation—has been on the whole uniform]

"Such an element is sodium. We take for this calculation the element alone, thus avoiding the obscure question of its ionization, which does not concern the issue. The quantity of sodium now in the sea, and the annual rate of its supply by the rivers, lead, it will be seen, to the deduction that the age of the Earth is 99 million years. Certain deductions from this are—it will be shown—warranted, so that the final result of this paper will be to show that the probable age is about 89 million years. Also, that this is probably a major limit, and that considerable departure from uniformity of activities could hardly amend it to less than 80 million years."

The actual calculation is very simple, since in the first place the total mass of the ocean is known approximately and also its composition, hence the total amount of sodium now present in it is obtained; further, the total amount of water discharged by the rivers into the ocean is known, with their average percentage of solid matter, sodium included, and this gives the mass of sodium annually added to the ocean. The quotient obtained is 99,400,000 years.

A minute discussion is given as to the probable original condition of the ocean and the state in which the chlorine now combined as sodium chloride probably existed. It is concluded that of the total chlorine in the original ocean, probably some 14 per cent may have existed as sodium chloride derived from the rapid denudation of the original rocks. This conclusion is based on the view that the chlorine now in the ocean must have been originally free in the atmosphere and hydrosphere, probably combined with hydrogen. The first result, (1) 99.4 millions of years, obtained, as stated, on the assumption that no free acid existed in the primeval atmosphere and that the total river supply of sodium was derived at a uniform rate from the rocks, is now (2) reduced to 86.9 million, assuming that the free acid in the original atmosphere (see above), less that subsequently supplied by rivers, attacked the original rocks and became neutralized in a negligible time. This again (3) becomes 89 millions if a period of acid denudation at a rate five times the average rate of present sub-aerial denudation is assumed. And finally (4) the result 89.3 millions of years is obtained in a fourth assumption that 10 p. c. of the sodium chloride in the river discharge was derived from the ocean.

Account is taken of the deposits of rock salt at various points, as, for instance, the salt range of the Punjab; but it is shown that the amount involved is relatively so small as not to seriously affect the problem. Other points are also considered, as to the probable uniformity of denudation by solution dependent upon land area and rainfall; also the solvent denudation of the ocean itself; but for the details of these, reference must be made to the original memoir.

One interesting relation brought out in the discussion is that existing between the soda (Na_2O) and potash (K_2O) in the aver-

age igneous and eruptive crust-rock as compared with that in sediments. The ratio, as obtained by Clarke, is $3.61:2.83$, or $\text{Na}_2\text{O}:\text{K}_2\text{O} = 1.29:1$. From rock analyses quoted by Rosenbusch, the ratio 1.22 is obtained. For sedimentary rocks, however, the ratio (from Rosenbusch) $0.59:1$ is obtained. The author discusses the bearing of these facts and finally concludes that "whereas the sodium compounds tend to accumulate in the waters of the ocean, the potassium compounds tend to be stored in the solid form or retained upon the land; and that to the causes which bring about this separation, and not to any differences in part processes of denudation, the remarkable scarcity in the ocean of potassium relatively to sodium is to be ascribed."

As connected with the same subject he notes that while roofing slates of Cambrian or Silurian age (quoting Rosenbusch and Clarke) contain 4.1 to 5.6 p. c. alkalies, and Devonian slates have 3.04 to 3.54 ; recent sediments contain a much smaller amount, e. g. 1.47 p. c. in the case of the Rhine, 1.96 for the Nile, etc.

3. *Recent Publications of the United States Geological Survey*, Charles D. Walcott, Director.—The following volumes have been recently issued by the U. S. Geological Survey:

NINETEENTH ANNUAL REPORT FOR 1897-98. Part I, *Director's Report*, including Triangulation and Surveying (see this Journal, vol. vii, p. 166).

Part IV, *Hydrography*, F. H. NEWELL, Chief of Division. Pp. viii, 814 with plates I to CXVIII. The results of the recent work in this highly important department of the Survey are now presented by themselves in a single volume of generous dimensions. For ten years past observations have been systematically carried on, having as their object the collection of data in regard to the fluctuation of the waters of prominent streams throughout the United States. The importance of the knowledge thus gained both from an economic and a scientific standpoint can readily be estimated. The opening chapter of the present volume by F. H. Newell, assisted by various observers (pp. 1-633), explains with numerous illustrations the methods of work, and then goes on to give the results of measurements of different rivers taken in natural geographical order. Among the special reports included may be mentioned one by Dwight Porter (pp. 34-111) on the streams of Maine and another by J. P. Lippincott (pp. 540-632) on the water supply of San Bernardino valley. The latter report is especially interesting as giving with many illustrations an account of the method of storing and distributing water, and the striking results so obtained, in a region which depends almost entirely upon artificial irrigation. Special chapters on the rock waters of Ohio, by Edward Orton (pp. 633-718, plates LXXI-LXXIII), and on the geology and water resources of Nebraska west of the 103d meridian by N. H. Darton (pp. 710-780, plates LXXIV-CXVIII) also contain much interesting matter.

Part VI. *Mineral Resources of the United States for 1897*, DAVID T. DAY, Chief of Division. This report, the fourteenth

of the series, appears in two volumes, each separately paged and indexed. The first (pp. 651) contains the Metallic Products with coal and coke, the second (pp. 706) Non-metallic Products except coal and coke. The value and scope of this report, to which many specialists have contributed, are too well known to need further comment here.

MONOGRAPHS: XXXI, *Geology of the Aspen Mining District, Colorado*, by JOSIAH EDWARD SPURR, pp. xxxv, 60. With an Atlas containing folio plates. This report will be noticed later.

Also XXIX by B. K. EMERSON and XXXI by the late JOHN STRONG NEWBERRY; both of these are noticed below.

BULLETIN, No. 162. *Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy* for 1898, by FRED BOUGHTON WEEKS. The value of this series is much increased by the admirable promptness with which the successive numbers appear.

4. *Geology of Old Hampshire County, Massachusetts, comprising Franklin, Hampshire, and Hampden Counties*, by BENJAMIN KENDALL EMERSON, pp. 1-782, plates i-xxxv, 1898. U. S. Geological Survey, Charles D. Walcott, Director. Monograph XXIX.—This elaborate description of the geology of central Massachusetts was begun in 1873, and thus contains the mature opinions of the author, based on a detailed study of the region. The classification of the rocks, which (except the Triassic sandstone) are crystalline limestones, granite schists, gneisses and diabases, is constructed on a chronologic basis.

The following general section of the rocks in the Berkshire hills and Connecticut valley will indicate the author's interpretation and the names adopted in the report:

Trias.

Black Rock diabase (intrusive).
Chicopee shale.
Longmeadow sandstone.
Granby tuff.
Mount Holyoke diabase (interbedded).
Sugar Loaf arkose.
Mount Toby conglomerate.
Unconformity.

Eruptives, mostly post-Carboniferous.

Granite.
Granitite.
Pegmatite.
Albitic granite.
Tonalite.

Carboniferous (no representative in the region).

Devonian.

Bernardston mica-schist.
Bernardston amphibolite.
Bernardston quartzite.
Bernardston limestone.
Vernon gneiss.
Unconformity.

Upper Silurian.

Leyden argillite.

Conway dark corrugated mica-schist with garnets.

Goshen flaggy biotitic muscovite-schist with quartzite and limestone beds.

Unconformity.

Lower Silurian.

Hawley actinolitic chlorite-schist, amphibolite, pyrite, and hematite beds.

Savoy chloritic sericite-schist.

Chester amphibolite, with emery, serpentine, steatite, and saxonite.

Rowe quartzose sericite-schist with amphibolite beds.

Hoosac albitic sericite schist.

Cambrian.

Cheshire white granular quartzite.

Becket white conglomerate-gneiss.

Unconformity.

Algonkian.

Washington blue quartz-gneiss.

Tyringham stretched biotite-gneiss.

East Lee black biotite-hornblende-gneiss.

Hinsdale coarse chondrodite-limestone.

Hinsdale granitoid gneiss.

w.

5. *The Later Extinct Floras of North America*, by JOHN STRONG NEWBERRY; A Posthumous Work, edited by ARTHUR HOLLICK, pp. i-xvii, 1-295, plates i-xlvi, 1898. U. S. Geological Survey, Charles D. Walcott, Director, Monograph XXXV. —In this volume are included illustrations of 174 species of Cretaceous and Tertiary plants, gathered from 52 localities of North America, together with such notes and descriptions as were found among his manuscript after Dr. Newberry's death.

Figures of some of the species have been previously distributed and names (MSS.) published, but in the present work all unpublished descriptions and notes found among the author's papers are edited and their reference to the figures indicated by the editor, Dr. Hollick, whenever clear, and whenever uncertain with the editor's comments.

w.

6. *Geological Survey of New Jersey, Annual Report of the State Geologist for the Year 1898*, pp. 1-244 and 1-100, plates i-v and i-xxii, 1899.—Besides the customary reports on various geological problems, an appendix of more than ordinary interest is furnished by GIFFORD PINCHOT on "A study of Forest Fires and Wood Production," illustrated by numerous photographic reproductions of the effects of the fires upon the forests in general and the individual trees of various ages.

w.

7. *Report on the Surface Geology and Auriferous Deposits of Southeastern Quebec*, by R. CHALMERS, pp. 5-160, plate i. Geological Survey of Canada, Annual Report, vol. X, 1898, G. M.

Dawson, Director. Part J, No. 670.—The gold-bearing region described in this report extends from Memphremagog Lake on the west, to the Etchemin River and Township of Ware on the northeast, and from the crystalline range of mountains nearest the St. Lawrence (the Sutton Mountain anticline) southeastward to the International boundary.

The author concludes from his study of the region that the "original source of this precious metal was in the oldest rocks of the 'Eastern Townships,' namely the pre-Cambrian or Huronian (?) of the three mountain ranges which traverse it. The Cambrian and Cambro-Silurian rocks are probably composed largely of materials derived from the pre-Cambrian in their disintegration and waste, and the gold they contain, as well as that met with in the alluviums derived from them, probably owes its origin likewise to the same source. Concentrating processes have been in operation ever since. During the formation of the Cambrian and Cambro-Silurian rocks there may have been some mechanical concentration of the gold in these, as the sediments which were derived from the pre-Cambrian in Cambrian and Cambro-Silurian times would naturally contain it in a fine state of division. It is difficult except on this supposition to account for its presence in some areas and its scarcity or absence in others. But the chief concentration seems to have been in some of the quartz veins at a later stage in areas of eruptive diorites and other intrusive rocks, and still later in the alluviums of the river-valleys during the wear and waste of the land surface."

W.

8. *The History of the European Fauna*, by R. F. SCHARFF, pp. 1-364, 1899 (The Contemporary Science Series, Walter Scott).—This book is a study in the origin and migration of the component elements of a living fauna. The present fauna of Britain is recognized as having its origin in migration to the region of an Arctic, a Siberian, an Oriental, a Lusitanian (southwest Europe) and an Alpine fauna. Regarding the time and order of these migrations, the author says, "there is considerable difference of opinion on this subject. Some believe that the British fauna is altogether post-glacial; a few think that it is partly so and the remainder glacial; others again hold that a portion is pre-glacial and the rest glacial and post-glacial. Those who have studied the subject most closely feel convinced that the southwestern or Lusitanian fauna, and also the flora, must have arrived before the Glacial period and survived the latter in these Islands. It seems reasonable to suppose, therefore, that the climate cannot have been very severe during the so-called Ice-Age. This Lusitanian fauna must be looked upon as the oldest portion of the British fauna. The Alpine and Oriental migrations arrived next. After these came the Arctic, and finally the Eastern or Siberian. As the fossil evidence is most complete with regard to the last, we are able to determine with precision not only the direction whence this migration came, but approximately its geological age. It arrived in Germany from the east after the deposition of the

lower boulder-clay. Since the boulder-clay is looked upon as a glacial deposit, the Siberian migration reached Central Europe after the first portion of the Glacial period had passed. In England it makes its first appearance in the Forest-Bed, which would therefore correspond to the 'Loess' formation of Central Europe. All the other migrations are older than the Siberian. They must therefore have come to Great Britain during the earlier part of the Glacial period or before it." W.

9. *The Geology of the Coolgardie Gold field*; by TORRINGTON BLATCHFORD, Assistant Government Geologist. Bulletin No. 3, Western Australia Geological Survey, A. Gibb Maitland, Government Geologist. Perth, 1899.—The Coolgardie gold field is remarkable for its rapid development—it was discovered in 1892—and for the richness of much of the ore. The prevailing rocks are designated as diorite with adjacent hornblendic and talcose schists, both intersected by numerous acid igneous dikes; a mass of granite is central in the district. Superficial deposits, in part "ironstone gravel," cover much of the region. The gold has been largely obtained from "gold reefs" intersecting the schists chiefly and dipping eastward at an angle of 60° to 80°. In addition gold has been obtained also from lenticular ferruginous patches and altered schists adjoining the igneous dikes. The alluvial deposits have also yielded much gold. The gold exported in 1894 amounted to 105,330 oz. and 1898 to 127,227 oz. The development of the region is much retarded by the deficient water supply. The average rainfall for the five years from 1894 to 1898 was only 7.01 inches, and artesian wells, though repeatedly tried, have not proved successful.

A large colored geological map of the region, on a scale of 8 inches to the mile, has been issued, in addition to the smaller one accompanying the report.

10. *Mineral Resources of Kansas for 1899*, by ERASMUS HAWORTH. Annual Bulletin of the University Geological Survey of Kansas, pp. 127, 1899, Lawrence, Kansas.—This second annual bulletin on the mineral resources of Kansas has recently been issued and contains an account of the lead and zinc mining, coal, oil, and gas, gypsum, building stone and clays, hydraulic cement, and salt.

The salt industry is of especial importance in the State, and the account here given of its discovery in 1887-88 and its rapid development is very interesting. Prof. Haworth, speaking of the geology of the Kansas salts, distinguishes between (1) the salt of salt marshes and of salt plains, chiefly in the northern part of the State, where the salt has been obtained from the shales of the Dakota formation; and (2) the rock salt of Central Kansas, which has been located in "salt shales" of the Permian. The thickness of the salt deposits diminishes eastward, though the exact extent on the west side of the salt lake from which the material was precipitated is as yet unknown. In a north and south direction the known salt beds cover a wider area, reaching from Anthony to

Kanopolis, thinning out northward. Thus the salt beds at Kingman are 415 feet in thickness; at Hutchinson, 380 feet; at Lyons, 275 feet, and at Kanopolis only 250. At this rate they would disappear entirely before the north line of the State is reached. It is a remarkable fact that the usual gypsum deposits do not seem to be present at localities just named, though largely represented to the northeast in Marshall County. In regard to this, Professor Haworth writes :

"It is difficult to understand how such extensive deposits of salt could be formed without a larger amount of gypsum being formed underneath them. The records of the wells at Kanopolis, Lyons, Hutchinson, Kingman and Anthony contain no reference to gypsum immediately underlying the salt beds. The question is as to what became of the calcium sulphate held in solution by the ocean water from which the rock salt was obtained. It is barely possible that during the period of the formation of the Marshall County gypsum the inland sea did not reach southward to the salt beds area, and that after gypsum was principally precipitated out of the enclosed ocean water and before concentration was carried far enough to precipitate the salt, surface movements resulted in draining this partially purified water southward over new areas from which fresh ocean water was excluded, thus permitting the continued evaporation to deposit the salt now found in the salt beds from the same water from which the Marshall County gypsum was produced. It is known that the Permian rocks, in general, become quite thin northward, entirely excluding the upper members of the Permian. So far as this has a bearing on the subject, it would tend to favor the view just expressed."

11. *Catalogus Mammalium tam viventium quam fossilium a Doctore E. L. TROUESSART, Parisiis. Nova Editio (Prima completa). Fasciculus VI. Appendix (Addenda et Corrigenda). Index alphabeticus.* pp. 1265-1469. Berlin, 1899 (R. Friedländer & Sohn).—The sixth and concluding part of this highly important work has recently been issued. It consists of an Appendix (pp. 1265-1360) containing Addenda and Corrigenda; also an exhaustive alphabetical index (pp. 1361-1469). The thoroughness with which the whole undertaking has been carried through makes it an invaluable book of reference to all zoologists.

12. *Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen.* Herausgegeben von der Deutschen Zoologischen Gesellschaft. Generalredakteur, FRANZ EILHARD SCHULZE. 5. Lieferung. *Protozoa.* Redakteur: O. BÜTSCHLI. *Sporozoa* par ALPHONSE LABBÉ. pp. 180 with 196 figures. Berlin, 1899 (R. Friedländer & Sohn).—Another work of similar exhaustive character to the above and broader scope is "Das Tierreich," published by the German Zoological Society. Earlier numbers have been repeatedly noticed in these pages. The present part, No. 5, contains the Sporozoa by Alphonse Labbé,

conservateur of the zoological collections of the Sorbonne at Paris. The classified species are briefly characterized with numerous references to authorities. Many illustrations accompany the text.

13. *Zoological Results based on Material from New Britain, New Guinea, Loyalty Islands and elsewhere*, collected during the years 1895, 1896, and 1897; by ARTHUR WILLEY. Part III, (May, 1899), pp. 207-356. Cambridge, 1899 (University Press).—Parts I and II of this work have already been noticed; the third part, recently issued, contains the following papers: Orthogenetic variation in the shells of *Chelonia*, by Hans Gadow; pp. 207-222, plates xxiv-xxv. Enteropneusta from the South Pacific, with notes on the West Indian Species, by Arthur Willey; pp. 223-334, plates xxvi-xxxii. A collection of Echiurids from the Loyalty Islands, New Britain and China Straits, with an attempt to revise the group and to determine its geographical range, by Arthur E. Shipley; pp. 335-356, plate xxxii.

14. *Proceedings of the Fourth International Congress of Zoology*. Cambridge, 22nd-27th August, 1898. Edited by ADAM SEDGWICK, M.A., F.R.S; pp. xv and 432 with 15 plates. London, 1899 (C. J. Clay & Sons).—This valuable volume has recently been issued and contains, in addition to the account of the meetings of the Congress at Cambridge in 1898, a large number of papers presented at that time, with the discussions which accompanied their reading.

15. *The Birds of Eastern North America: Water Birds*. Part I. Key to the Families and Species. By CHARLES B. CORY, Curator of the Department of Ornithology in the Field Columbian Museum. Pp. ix, 142.—This excellent and liberally illustrated volume appears as a special edition printed for the Field Columbian Museum.

16. *A Hand-list of the Genera and Species of Birds*; by R. BOWDLER SHARPE, LL.D. Vol. I, pp. xxi and 303, London, 1899.—This recent addition to the Catalogues published under the auspices of the British Museum, including species both recent and fossil, has been carefully prepared by Dr. Sharpe of the Zoological Department. Many ornithologists at home and abroad have contributed to its accuracy and completeness.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Physical Society*.—A meeting of the recently organized American Physical Society was held in Fayerweather Hall, Columbia University, New York City, on October 28th. The program announces the presidential address delivered by Professor Henry A. Rowland and papers read by various of the members. Four regular meetings of the Society are proposed for each year, ordinarily to be held in New York; the annual meeting is appointed for the last week of December. The Society will issue a Bulletin containing reports of the meetings with notices of papers read or presented. The Secretary of the Society is Professor Ernest Merriitt.

2. *Transactions of the American Microscopical Society*, edited by the Secretary. Twenty-first annual meeting held at Syracuse, N. Y., August 30th, 31st, and September 1st, 1899. Vol. xx, pp. 369 with 32 plates.—The latest volume of the Transactions of the American Microscopical Society, just published, contains the usual number of valuable papers. Among the more extended of these may be mentioned the following: Contributions to the histogenesis of the Caryophyllales, I, by F. E. Clements, pp. 97-164, with plates viii to xxv; the North American species of the genus *Atax* (Fabr.) Bruz, by R. H. Wolcott, pp. 193-260, with plates xxviii-xxxii; Fresh water investigations during the last five years, by Henry B. Ward, pp. 261-336.

A paper by A. Mansfield Holmes (pp. 177-188) gives the results of some observations as to the effect of altitude on the red blood cells. It is shown that a sudden change from a low to a high altitude produces a rapid increase in the number of red cells, and a descent to a lower altitude, a rapid decrease. The former change, however, takes place immediately, the number continuing to increase during a residence on a mountain; but the diminution on descent, though rapid, is not so pronounced as the rate of increase. The effect of altitude is thus explained: that the increasing need of oxygen at higher points calls for greater activity of the total volume of red cells and brings, therefore, into activity many which under different conditions would remain more or less quiescent in deeper portions of the body.

3. *A Primer of Forestry*. Part I: The Forest. By GIFFORD PINCHOT; pp. 88 with 47 plates. Washington, 1899. Bulletin No. 4, U. S. Department of Agriculture, Division of Forestry.—This little book, with its numerous illustrations, presents in very attractive form the subject of forestry newly developed in this country, and which, under the guidance of Mr. Pinchot and others, it is hoped will yield important fruit. The author shows how a forest is to be regarded as an organic whole, and traces its progress through the time of full maturity to the inevitable end. An interesting chapter is that devoted to the numerous enemies of the forest, as fire, the reckless use of the axe, insects, and others.

4. *Statistical Methods with special reference to Biological Variation*; by C. B. DAVENPORT, Harvard University. New York, 1899 (John Wiley & Sons).—This little volume contains in very concise and clear form a series of mathematical tables, formulas, etc., likely to prove valuable to the working biologist in his statistical work on recently developed lines. The subjects of the preliminary chapters are: The methods of measuring organisms; the seriation and plotting of data and the frequency polygons; the classes of frequency polygons; correlated variability. The mathematical tables follow, accompanied by concise explanations as to their use.

5. *Harper's Scientific Memoirs*, edited by J. S. AMES, Ph.D. Volumes v, vi, and vii of this valuable series (see vol. vi, pp. 199, 504) have been recently issued. Their subjects are as follows:

The Laws of Gases. Memoirs by Robert Boyle and E. H. Amagat. Translated and edited by Professor Carl Barus.

The Second Law of Thermodynamics. Memoirs by Carnot, Clausius, and Thomson. Translated and edited by Dr. W. F. Magie.

The Fundamental Laws of Electrolytic Conduction. Memoirs by Faraday, Hit-
torf, and F. Kohlrausch. Translated and edited by Dr. H. M. Goodwin.

OBITUARY.

EDWARD ORTON, Professor of Geology in the Ohio State University, died at Columbus, Ohio, Oct. 16th, in the seventieth year of his age. Professor Orton is chiefly known among scientific men by his contributions to Geology. Since 1865, he has been a resident of Ohio, and, while his labors have extended to all branches of geological science, his close watch of the exploitation of petroleum and natural gas, in his own and the neighboring States of Pennsylvania and Indiana, has given him a place of pre-eminence as interpreter of these important geological products. He took part in the preparation of volumes 1, 2 and 3, of the reports of the Geological Survey of the State of Ohio, and as State Geologist, issued volumes 4, 5, 6 and 7. He was appointed State Geologist in 1882, and has held that position up to the present year. In 1897, he was elected president of the Geological Society of America, and as president of the American Association for the Advancement of Science, presided at the recent meeting of the Association, in Columbus, in August last. Professor Orton was a man of broad culture and of influence outside his chosen science. Born at Deposit, Delaware Co., N. Y., he entered Hamilton College, graduating in 1848. He spent a year in the Lane Theological Seminary, and in 1852, took a course of studies in chemistry and botany at the Lawrence Scientific School. For three years he was professor of Natural Science in the State Normal School at Albany. He was for a time president of Antioch College, Yellow Springs, Ohio, and then became president of the Ohio Agricultural and Mechanical College, which has now become the State University. He resigned the presidency and became State Geologist in 1882. He was greatly beloved and esteemed by those who knew him. A fellow-townsmen writes of him as follows: "In him were combined the deep thinking of the philosopher, the research of the scholar, the impulses of an honorable man, the manners of a gentleman, combined with infinite liberality, toleration and affability. As teacher, lecturer, college president and man he distinguished himself from his fellow-men without falling victim to the pride which too often goes hand in hand with greatness." Dr. Orton received the degree of Ph.D. from Hamilton College in 1848, and LL.D. from Ohio State University in 1881.

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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLV.—*The Highest Aim of the Physicist*; by HENRY A. ROWLAND.

[ADDRESS DELIVERED TO THE PHYSICAL SOCIETY OF AMERICA BY THE PRESIDENT AT ITS MEETING IN NEW YORK, OCTOBER 28, 1899.]

GENTLEMEN AND FELLOW PHYSICISTS OF AMERICA—We meet to-day on an occasion which marks an epoch in the history of physics in America; may the future show that it also marks an epoch in the history of the science which this society is organized to cultivate! For we meet here in the interest of a science above all sciences which deals with the foundation of the Universe, with the constitution of matter from which everything in the Universe is made and with the ether of space by which alone the various portions of matter forming the Universe affect each other even at such distances as we may never expect to traverse whatever the progress of our science in the future.

We, who have devoted our lives to the solution of problems connected with physics, now meet together to help each other and to forward the interests of the subject which we love. A subject which appeals most strongly to the better instincts of our nature and the problems of which tax our minds to the limit of their capacity and suggest the grandest and noblest ideas of which they are capable.

In a country where the doctrine of the equal rights of man has been distorted to mean the equality of man in other respects, we form a small and unique body of men, a new variety of the human race as one of our greatest scientists calls it, whose views of what constitutes the greatest achievement in life are very different from those around us. In this respect we form an aristocracy, not of wealth, not of pedigree, but of

intellect and of ideals, holding him in the highest respect who adds the most to our knowledge or who strives after it as the highest good.

Thus we meet together for mutual sympathy and the interchange of knowledge, and may we do so ever with appreciation of the benefits to ourselves and possibly to our science. Above all, let us cultivate the idea of the dignity of our pursuit so that this feeling may sustain us in the midst of a world which gives its highest praise, not to the investigation in the pure etherial physics which our society is formed to cultivate, but to the one who uses it for satisfying the physical rather than the intellectual needs of mankind. He who makes two blades of grass grow where one grew before is the benefactor of mankind; but he who obscurely worked to find the laws of such growth is the intellectual superior as well as the greater benefactor of the two.

How stands our country, then, in this respect? My answer must still be now as it was fifteen years ago, that much of the intellect of the country is still wasted in the pursuit of so-called practical science which ministers to our physical needs and but little thought and money is given to the grander portion of the subject which appeals to our intellect alone. But your presence here gives evidence that such a condition is not to last forever.

Even in the past we have a few names whom scientists throughout the world delight to honor. Franklin, who almost revolutionized the science of electricity by a few simple but profound experiments. Count Rumford, whose experiments almost demonstrated the nature of heat. Henry, who might have done much for the progress of physics had he published more fully the results of his investigations. Mayer, whose simple and ingenious experiments have been a source of pleasure and profit to many. This is the meager list of those whom death allows me to speak of and who have earned mention here by doing something for the progress of our science. And yet the record has been searched for more than a hundred years. How different had I started to record those who have made useful and beneficial inventions!

But I know, when I look in the faces of those before me, where the eager intellect and high purpose sit enthroned on bodies possessing the vigor and strength of youth, that the writer of a hundred years hence can no longer throw such a reproach upon our country. Nor can we blame those who have gone before us. The progress of every science shows us the condition of its growth. Very few persons, if isolated in a semi-civilized land, have either the desire or the opportunity of pursuing the higher branches of science. Even if they

should be able to do so, their influence on their science depends upon what they publish and make known to the world. A hermit philosopher we can imagine might make many useful discoveries. Yet, if he keeps them to himself, he can never claim to have benefited the world in any degree. His unpublished results are his private gain, but the world is no better off until he has made them known in language strong enough to call attention to them and to convince the world of their truth. Thus, to encourage the growth of any science, the best thing we can do is to meet together in its interest, to discuss its problems, to criticise each other's work and, best of all, to provide means by which the better portion of it may be made known to the world. Furthermore, let us encourage discrimination in our thoughts and work. Let us recognize the eras when great thoughts have been introduced into our subject and let us honor the great men who introduced and proved them correct. Let us forever reject such foolish ideas as the equality of mankind and carefully give the greater credit to the greater man. So, in choosing the subjects for our investigation, let us, if possible, work upon those subjects which will finally give us an advanced knowledge of some great subject. I am aware that we cannot always do this: our ideas will often flow in side channels: but, with the great problems of the Universe before us, we may sometime be able to do our share toward the greater end.

What is matter; what is gravitation; what is ether and the radiation through it; what is electricity and magnetism; how are these connected together and what is their relation to heat? These are the greater problems of the universe. But many infinitely smaller problems we must attack and solve before we can even guess at the solution of the greater ones.

In our attitude toward these greater problems how do we stand and what is the foundation of our knowledge?

Newton and the great array of astronomers who have succeeded him have proved that, within planetary distances, matter attracts all others with a force varying inversely as the square of the distance. But what sort of proof have we of this law? It is derived from astronomical observations on the planetary orbits. It agrees very well within these immense spaces; but where is the evidence that the law holds for smaller distances? We measure the lunar distance and the size of the earth and compare the force at that distance with the force of gravitation on the earth's surface. But to do this we must compare the matter in the earth with that in the sun. This we can only do by *assuming* the law to be proved. Again, in descending from the earth's gravitation to that of two small bodies, as in the Cavendish experiment, we *assume*

the law to hold and deduce the mass of the earth in terms of our unit of mass. Hence, when we say that the mass of the earth is $5\frac{1}{2}$ times that of an equal volume of water we *assume* the law of gravitation to be that of Newton. Thus a proof of the law from planetary down to terrestrial distances is physically impossible.

Again, that portion of the law which says that gravitational attraction is proportional to the quantity of matter, which is the same as saying that the attraction of one body by another is not affected by the presence of a third, the feeble proof that we give by weighing bodies in a balance in different positions with respect to each other cannot be accepted on a larger scale. When we can tear the sun into two portions and prove that either of the two halves attracts half as much as the whole, then we shall have a proof worth mentioning.

Then as to the relation of gravitation and time what can we say? Can we for a moment suppose that two bodies moving through space with great velocities have their gravitation unaltered? I think not. Neither can we accept Laplace's proof that the force of gravitation acts instantaneously through space, for we can readily imagine some compensating features unthought of by Laplace.

How little we know then of this law which has been under observation for two hundred years!

Then as to matter itself how have our views changed and how are they constantly changing. The round hard atom of Newton which God alone could break into pieces has become a molecule composed of many atoms, and each of these smaller atoms has become so elastic that after vibrating 100,000 times its amplitude of vibration is scarcely diminished. It has become so complicated that it can vibrate with as many thousand notes. We cover the atom with patches of electricity here and there and make of it a system compared with which the planetary system, nay the universe itself, is simplicity. Nay more: some of us even claim the power, which Newton attributed to God alone, of breaking the atom into smaller pieces whose size is left to the imagination. Where, then, is that person who ignorantly sneers at the study of matter as a material and gross study? Where, again, is that man with gifts so God-like and mind so elevated that he can attack and solve its problem?

To all matter we attribute two properties, gravitation and inertia. Without these two matter cannot exist. The greatest of the natural laws states that the power of gravitational attraction is proportional to the mass of the body. This law of Newton, almost neglected in the thoughts of physicists, undoubtedly has vast import of the very deepest meaning. Shall it mean that all matter is finally constructed of uniform

and similar primordial atoms or can we find some other explanation?

That the molecules of matter are not round, we know from the facts of crystallography and the action of matter in rotating the plane of polarization of light.

That portions of the molecules and even of the atoms are electrically charged, we know from electrolysis, the action of gases in a vacuum tube and from the Zeeman effect.

That some of them act like little magnets, we know from the magnetic action of iron, nickel and cobalt.

That they are elastic, the spectrum shows, and that the vibrating portion carries the electrified charge with it is shown by the Zeeman effect.

Here, then, we have made quite a start in our problem: but how far are we from the complete solution? How can we imagine the material of which ordinary or primordial atoms are made, dealing as we do only with aggregation of atoms alone? Forever beyond our sight, vibrating an almost infinite number of times in a second, moving hither and yon with restless energy at all temperatures beyond the absolute zero of temperature, it is certainly a wonderful feat of human reason and imagination that we know as much as we do at present. Encouraged by these results, let us not linger too long in their contemplation but press forward to the new discoveries which await us in the future.

Then as to electricity, the subtle spirit of the amber, the demon who reached out his gluttonous arms to draw in the light bodies within his reach, the fluid which could run through metals with the greatest ease but could be stopped by a frail piece of glass! Where is it now? Vanished, thrown on the waste heap of our discarded theories to be replaced by a far nobler and exalted one of action in the ether of space.

And so we are brought to consider that other great entity—the ether: filling all space without limit, we imagine the ether to be the only means by which two portions of matter distant from each other can have any mutual action. By its means we imagine every atom in the universe to be bound to every other atom by the force of gravitation and often by the force of magnetic and electric action, and we conceive that it alone conveys the vibratory motion of each atom or molecule out into space to be ever lost in endless radiation, passing out into infinite space or absorbed by some other atoms which happen to be in its path. By it all electromagnetic energy is conveyed from the feeble attraction of the rubbed amber through the many thousand horse-power conveyed by the electric wires from Niagara to the mighty rush of energy always flowing from the Sun in a flood of radiation. Actions feeble and

actions mighty from inter-molecular distances through inter-planetary and inter-stellar distances until we reach the mighty distances which bound the Universe—all have their being in this wondrous ether.

And yet, however wonderful it may be, its laws are far more simple than those of matter. Every wave in it, whatever its length or intensity, proceeds onwards in it according to well known laws, all with the same speed, unaltered in direction from its source in electrified matter, to the confines of the Universe unimpaired in energy unless it is disturbed by the presence of matter. However the waves may cross each other, each proceeds by itself without interference with the others.

So with regard to gravitation, we have no evidence that the presence of a third body affects the mutual attraction of two other bodies or that the presence of a third quantity of electricity affects the mutual attraction of two other quantities. The same for magnetism.

For this reason the laws of gravitation and of electric and magnetic action including radiation are the simplest of all laws when we confine them to a so-called vacuum, but become more and more complicated when we treat of them in space containing matter.

Subject the ether to immense electrostatic, magnetic or gravitational forces and we find absolutely no signs of its breaking down or even change of properties. Set it into vibration by means of an intensely hot body like that of the sun and it conveys many thousand horse-power for each square foot of surface as quietly and with apparently unchanged laws as if it were conveying the energy of a tallow dip.

Again, subject a millimeter of ether to the stress of many thousand, nay even a million, volts and yet we see no signs of breaking down.

Hence the properties of the ether are of ideal simplicity and lead to the simplest of natural laws. All forces which act at a distance, always obey the law of the inverse square of the distance and we have also the attraction of any number of parts placed near each other equal to the arithmetical sum of the attractions when those parts are separated. So also the simple law of etherial waves which has been mentioned above.

At the present time, through the labors of Maxwell supplemented by those of Hertz and others, we have arrived at the great generalization that all wave disturbances in the ether are electromagnetic in their nature. We know of little or no etherial disturbance which can be set up by the motion of matter alone: the matter must be electrified in order to have sufficient hold on the ether to communicate its motion to the ether. The Zeeman effect even shows this to be the case

where molecules are concerned and when the period of vibration is immensely great. Indeed the experiment on the magnetic action of electric convection shows the same thing. By electrifying a disc in motion it appears as if the disc holds fast to the ether and drags it with it, thus setting up the peculiar ethereal motion known as magnetism.

Have we not another case of a similar nature when a huge gravitational mass like that of the earth revolves on its axis? Has not matter a feeble hold on the ether sufficient to produce the earth's magnetism?

But the experiment of Lodge to detect such an action apparently showed that it must be very feeble. Might not his experiment have succeeded had he used an electrified revolving disc?

To detect something dependent on the relative motion of the ether and matter has been and is the great desire of physicists. But we always find that, with one possible exception, there is always some compensating feature which renders our efforts useless. This one experiment is the aberration of light, but even here Stokes has shown that it may be explained in either of two ways: first, that the earth moves through the ether of space without disturbing it, and second, if it carries the ether with it by a kind of motion called irrotational. Even here, however, the amount of action probably depends upon *relative* motion of the luminous source to the recipient telescope.

So the principle of Döppler depends also on this relative motion and is independent of the ether.

The result of the experiments of Foucault on the passage of light through moving water can no longer be interpreted as due to the partial movement of the ether with the moving water, an inference due to imperfect theory alone. The experiment of Lodge, who attempted to set the ether in motion by a rapidly rotating disc, showed no such result.

The experiment of Michelson to detect the ethereal wind, although carried to the extreme of accuracy, also failed to detect any relative motion of the matter and the ether.

But matter with an electrical charge holds fast to the ether and moves it in the manner required for magnetic action.

When electrified bodies move together through space or with reference to each other we can only follow their mutual actions through very slow and uniform velocities. When they move with velocities comparable with that of light, equal to it or even beyond it, we calculate their mutual actions or action on the ether only by the light of our imagination unguided by experiment. The conclusions of J. J. Thomson, Heaviside and Hertz are all results of the imagination and they all rest

upon assumptions more or less reasonable but always assumptions. A mathematical investigation always obeys the law of the conservation of knowledge: we never get out more from it than we put in. The knowledge may be changed in form, it may be clearer and more exactly stated, but the total amount of the knowledge of nature given out by the investigation is the same as we started with. Hence we can never predict the result in the case of velocities beyond our reach, and such calculations as the velocity of the cathode rays from their electromagnetic action has a great element of uncertainty which we should do well to remember.

Indeed, when it comes to exact knowledge, the limits are far more circumscribed.

How is it, then, that we hear physicists and others constantly stating what will happen beyond these limits? Take velocities, for instance, such as that of a material body moving with the velocity of light. There is no known process by which such a velocity can be obtained even though the body fell from an infinite distance upon the largest aggregation of matter in the Universe. If we electrify it, as in the cathode rays, its properties are so changed that the matter properties are completely masked by the electromagnetic.

It is a common error which young physicists are apt to fall into to obtain a law, a curve or a mathematical expression for given experimental limits and then to apply it to points outside those limits. This is sometimes called extrapolation. Such a process, unless carefully guarded, ceases to be a reasoning process and becomes one of pure imagination specially liable to error when the distance is too great.

But it is not my purpose to enter into detail. What I have given suffices to show how little we know of the profounder questions involved in our subject.

It is a curious fact that, having minds tending to the infinite, with imaginations unlimited by time and space, the limits of our exact knowledge are very small indeed. In time we are limited by a few hundred or possibly thousand years: indeed the limit in our science is far less than the smaller of these periods. In space we have exact knowledge limited to portions of our earth's surface and a mile or so below the surface, together with what little we can learn from looking through powerful telescopes into the space beyond. In temperature our knowledge extends from near the absolute zero to that of the sun but exact knowledge is far more limited. In pressures we go from the Crookes vacuum still containing myriads of flying atoms to pressures limited by the strength of steel but still very minute compared with the pressures at the center of the earth and sun, where the hardest steel would flow like the

most limpid water. In velocities we are limited to a few miles per second. In forces to possibly 100 tons to the square inch. In mechanical rotations to a few hundred times per second.

All the facts which we have considered, the liability to error in whatever direction we go, the infirmity of our minds in their reasoning power, the fallibility of witnesses and experimenters, lead the scientist to be specially sceptical with reference to any statement made to him or any so-called knowledge which may be brought to his attention. The facts and theories of our science are so much more certain than those of history, of the testimony of ordinary people on which the facts of ordinary history or of legal evidence rest, or of the value of medicines to which we trust when we are ill, indeed to the whole fabric of supposed truth by which an ordinary person guides his belief and the actions of his life, that it may seem ominous and strange if what I have said of the imperfections of the knowledge of physics is correct. How shall we regulate our minds with respect to it: there is only one way that I know of and that is to avoid the discontinuity of the ordinary, indeed the so-called cultivated legal mind. There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.

The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases: the ideal scientific mind, however, has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as, if possible, to always keep it in its proper relation to truth and error. Thus the fluid nature of electricity was once in a compartment near the truth. Faraday's and Maxwell's researches have now caused us to move it to a compartment nearly up to that of absolute error.

So the law of gravitation within planetary distances is far toward absolute truth, but may still need amending before it is advanced farther in that direction.

The ideal scientific mind, therefore, must always be held in a state of balance which the slightest new evidence may change in one direction or another. It is in a constant state of skepticism, knowing full well that nothing is certain. It is above all an agnostic with respect to all facts and theories of science as well as to all other so-called beliefs and theories.

Yet it would be folly to reason from this that we need not

guide our life according to the approach to knowledge that we possess. Nature is inexorable; it punishes the child who unknowingly steps off a precipice quite as severely as the grown scientist who steps over, with full knowledge of all the laws of falling bodies and the chances of their being correct. Both fall to the bottom and in their fall obey the gravitational laws of inorganic matter, slightly modified by the muscular contortions of the falling object but not in any degree changed by the previous belief of the person. Natural laws there probably are, rigid and unchanging ones at that. Understand them and they are beneficent: we can use them for our purposes and make them the slaves of our desires. Misunderstand them and they are monsters who may grind us to powder or crush us in the dust. Nothing is asked of us as to our belief: they act unswervingly and we must understand them or suffer the consequences. Our only course, then, is to act according to the chances of our knowing the right laws. If we act correctly, right; if we act incorrectly, we suffer. If we are ignorant we die. What greater fool, then, than he who states that belief is of no consequence provided it is sincere.

An only child, a beloved wife, lies on a bed of illness. The physician says that the disease is mortal; a minute plant called a microbe has obtained entrance into the body and is growing at the expense of its tissues, forming deadly poisons in the blood or destroying some vital organ. The physician looks on without being able to do anything. Daily he comes and notes the failing strength of his patient and daily the patient goes downward until he rests in his grave. But why has the physician allowed this? Can we doubt that there is a remedy which shall kill the microbe or neutralize its poison? Why, then, has he not used it? He is employed to cure but has failed. His bill we cheerfully pay because he has done his best and given a chance of cure. The answer is *ignorance*. The remedy is yet unknown. The physician is waiting for others to discover it or perhaps is experimenting in a crude and unscientific manner to find it. Is not the inference correct, then, that the world has been paying the wrong class of men? Would not this ignorance have been dispelled had the proper money been used in the past to dispel it? Such deaths some people consider an act of God. What blasphemy to attribute to God that which is due to our own and our ancestors' selfishness in not founding institutions for medical research in sufficient number and with sufficient means to discover the truth. Such deaths are murder. Thus the present generation suffers for the sins of the past and we die because our ancestors dissipated their wealth in armies and navies, in the foolish pomp and circumstance of society, and neglected to

provide us with a knowledge of natural laws. In this sense they were the murderers and robbers of future generations of unborn millions and have made the world a charnel house and place of mourning where peace and happiness might have been. Only their ignorance of what they were doing can be their excuse, but this excuse puts them in the class of boors and savages who act according to selfish desire and not to reason and to the calls of duty. Let the present generation take warning that this reproach be not cast on it, for it cannot plead ignorance in this respect.

This illustration from the department of medicine I have given because it appeals to all. But all the sciences are linked together and must advance in concert. The human body is a chemical and physical problem, and these sciences must advance before we can conquer disease.

But the true lover of physics needs no such spur to his actions. The cure of disease is a very important object and nothing can be nobler than a life devoted to its cure.

The aims of the physicist, however, are in part purely intellectual: he strives to understand the Universe on account of the intellectual pleasure derived from the pursuit, but he is upheld in it by the knowledge that the study of nature's secrets is the ordained method by which the greatest good and happiness shall finally come to the human race.

Where, then, are the great laboratories of research in this city, in this country, nay, in the world? We see a few miserable structures here and there occupied by a few starving professors who are nobly striving to do the best with the feeble means at their disposal. But where in the world is the institute of pure research in any department of science with an income of \$100,000,000 per year. Where can the discoverer in pure science earn more than the wages of a day laborer or cook? But \$100,000,000 per year is but the price of an army or of a navy designed to kill other people. Just think of it, that one per cent of this sum seems to most people too great to save our children and descendants from misery and even death!

But the twentieth century is near—may we not hope for better things before its end? May we not hope to influence the public in this direction?

Let us go forward, then, with confidence in the dignity of our pursuit. Let us hold our heads high with a pure conscience while we seek the truth, and may the American Physical Society do its share now and in generations yet to come in trying to unravel the great problem of the constitution and laws of the Universe.

ART. XLVI.—*Notice of an Aerolite that recently fell at Allegan, Michigan*; by HENRY L. WARD.

[Announced before the Rochester Academy of Sciences, Oct. 10th.]

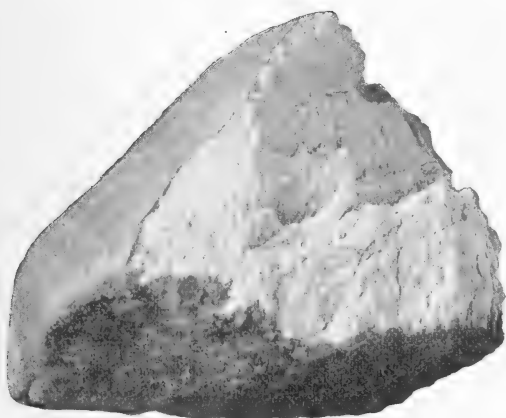
AT eight A. M. on Monday, July 10th, of the present year there fell at Allegan, Michigan (about 32 miles S.S.W. of Grand Rapids), the aerolite herein noticed. An account of the fall was published by the Allegan Gazette in its issue of July 15th; but as I have a report of this phenomenon directly from an eye-witness, who was very near where the stone struck, who assisted in its excavation, and who was a part owner of it, the information furnished by him has been used rather than that of the newspaper. Both agree, however, in their essential features.

The newspaper account states that a piece of the meteorite was reported to have fallen at Dunningville [about eight miles N.W. of Allegan] and another on the lake shore [the nearest point of which lies about 20 miles west of Allegan]. A resident of Dunningville informs me that this report is erroneous as far as that village is concerned; as no one in the village knew anything about it except from the published report. To the best of my knowledge nothing further has been heard of the piece reported to have fallen on the lake shore; so it is presumable that this assertion also is erroneous.

Mr. Walter Price, of Allegan, writes in answer to my inquiries: "I was working on the road when the meteorite struck; it fell inside the village limits in nearly the center of the street." The exact locality is the Thomas hill on the Saugatuck road. Mr. Price continues: "It came from the north-west, and passed within about forty feet from where we were working and struck about ten rods beyond in the sand (the road was a little sandy). The first we noticed we heard a report in the sky as if a large cannon had been fired, and after that there was a rumbling noise which lasted about five minutes (this is as near as I could guess). When we heard this rumbling sound we began to look up, and saw a black ball, about the size of a man's fist, coming our way. By this time the sound had changed to a noise very much like one caused by throwing a red-hot iron into a tub of water, and when it passed by it sounded like an engine blowing off steam. There seemed to be, also, a blue streak behind it about six feet long which tapered back to a sharp point. When the meteorite struck we saw the sand fly, and it was probably five minutes before we went to dig it up. The soil was sandy and it buried itself a foot and a half. When we had thrown the loose sand from over it, it was too hot for us to handle with our hands, and we

had to take a shovel to get it out of the hole. The sand was hot for about two feet around where it struck. I should think about one third of it broke into small pieces when it struck the ground. All the outside pieces had the black crust on them."

The temperature of this aerolite on reaching the earth was a matter of much interest to me. It seemed not improbable that such a large mass, said to have been about 20 inches long and 10 or 12 inches through in the thickest part, passing, for no one knows how long, through the intense cold of interstellar space should, as a mass, be cold upon reaching the earth; and that only the surface for a slight depth should become heated. Such, however, appears not to have been the case with this meteorite; which agreed with popular accounts that frequently ascribe great heat to them.



In a later communication Mr. Price writes: "In regard to the heat of the meteorite, as I understand your question, you would like to know whether it was hot all through or not. I am certain that it was hot clear through, for the pieces were all hot; and the four-pound piece I sent you was so hot that I had to keep changing it from one hand to the other in carrying it from where it fell to the wagon. As to the speed that it was traveling I cannot just express, but will say that while it was plainly visible it seemed to me that it was going at a swift speed."

The accompanying illustration is from a photograph made by a local photographer from the largest piece, said to have weighed 62½ lbs. This has not come into our hands.* We

* We, indeed, confidently expected to obtain it but the local merchant whose offer to act as our agent in its purchase we had accepted, on obtaining a clear title, proceeded to sell it to other parties who were, however, doubtless ignorant of our moral claim. Its whereabouts were unknown to us, when this article was written, but see the note beyond.

have, however, obtained for Ward's Natural Science Establishment various fragments through the agency of Mr. Price and consequently are able to describe the stone.

It is of a light ash-gray color, exceedingly friable; and covered with a black crust averaging about 1^{mm} in thickness, though in some parts reaching fully 2^{mm} , which varies from comparatively smooth in parts to wave-like crests on others.

The stone is very chondritic in structure; with the largest chondrules, composed of acicular crystals of enstatite, 3^{mm} in diameter, sparingly distributed through it. The greater number of the chondrules are much smaller; and many are very minute. An optical examination, without the use of polarized light, shows the presence of enstatite, chrysolite, some feldspar, troilite and iron. The troilite and iron are dispersed quite evenly and thickly as small irregularly-shaped grains. The specific gravity, taken from a large fragment of the stone without crust, is 3.558. No veins appear in the portions examined. Apparently this stone belongs to Meunier's group (33) called Montréjite.

The name proposed for this aerolite, *Allegan*, is fortunate in that it is at once the name of the town and of the county in which it fell.

Note.—Since the above was written I have learned that the larger mass of this aerolite is now in the U. S. National Museum at Washington.

ART. XLVII.—*Note on a New Meteoric Iron found near Iredell, Bosque County, Texas, U. S. A.;* by WARREN M. FOOTE.

IN July, 1899, the firm of Dr. A. E. Foote of Philadelphia, Pa., received from Mr. J. W. Jones of Rowlett, Texas, several ore samples for examination. Among them was a fragment of metallic iron bearing characteristic signs of meteoric origin. Later, all of the fragments of the original mass which could be traced, were purchased by the same firm. The finder supplied the following data in a certified statement: The original mass, roughly estimated at about three pounds weight and shaped like a large mussel-shell, was found by J. W. Jones while prospecting in June, 1898, on the eastern end of the Dudley sheep ranch, situated in the western corner of Bosque Co., Texas, about five or six miles southwest of the village of Iredell and one-half mile from the county line. It lay exposed in a rut seven inches deep, worn in an old road, on the west side of a small hill. The finder broke the mass, distributing pieces among strangers and passing acquaintances, who employed the metal in various ways, such as the making of knife-blades, etc. Over a year later some of these fragments were recovered, although it was impossible to get the slightest trace of a majority of them, constituting over half of the original specimen. A thorough search was made for other masses which might have fallen in the vicinity of the find, but without success.

The total weight of the known fragments is 500 grams. In exterior appearance this fall resembles most siderites, presenting an uneven, somewhat rusty surface with slight exudation of lawrencite; also streaks of schreibersite. The fragments are quite rough and angular, where broken. The three best instances of cleavage are exhibited in one specimen. These are three pairs of perfect, adjacent planes forming angles of 120° . Other less definite cleavages also indicate the crystallization to be dodecahedral. However these angles, although near one another, form no apparent relationship, which can be explained by the changes to which the mass has been subjected. It parts easily along the cleavage planes and following irregular fissures where the disintegration is most advanced. Fractured across these natural lines, it presents a glistening tin-white finely crystalline surface. Grains and plates, as much as 2^{mm} thick, of a brittle magnetic mineral, of pyritiferous aspect, are common. The smaller particles of this were so intimately mixed with the iron as to defy mechanical separation. A qualitative examination showed the presence of iron, phosphorus and nickel,

indicating it to be schreibersite. The iron is soft and takes a high polish. Treating polished surfaces with dilute nitric acid develops an etching barely visible to the unaided eye. This consists of innumerable and very minute pits in the plessite, with long very fine bright lines crossing at right angles and occasionally short diagonal lines.

The composition, determined by Mr. J. Edward Whitfield from a sample of the iron, only partially freed from schreibersite, is as follows:

Iron	93.75 per cent
Nickel	5.51
Cobalt .....	.52
Phosphorus .....	.20
Sulphur .....	.06

100.04

Several siderites found in Texas bear such a close geographical relationship to this one, as to demand comparison. These are: Carlton, found in 1888 about 12 miles to the southwest in Hamilton Co., with 12.77 per cent nickel; the Red River, found in 1836 in the adjacent county (Johnson), with 8.46 per cent nickel; and Denton Co., found in 1859 about 100 miles north, with 7.53 per cent nickel. However the most marked variations from the present find are the large and distinct Widmannstätten figures which appear on etching the neighboring irons. *Iredell* may, therefore, be safely accepted as a distinct fall.

Nov. 7th, 1899.

ART. XLVIII.—*On a New Occurrence of Nepheline Syenite in New Jersey*; * by F. LESLIE RANSOME.

Introduction.

THROUGH the kindness of Mr. N. H. Darton, there recently came into my hands a few rock-specimens which he had collected near Brookville, N. J., in the course of general areal work on the Trenton folio of the Geological Atlas of the U. S. The specimens were stated by him to have come from a mass of trap intrusive into the Newark formation, and were supposed, when collected, to be variations from the usual and normal facies of the common trap-rock of the region. Upon examination, one of the specimens proved to be a nepheline syenite, and two of the others hornblende and biotite syenites respectively. The original specimens furnished by Mr. Darton were studied petrographically, and a chemical analysis of the nepheline syenite was made by Mr. George Steiger of the Geological Survey. Subsequently a brief visit was paid to the locality, additional material secured, and some attempt made to ascertain the relation of the syenitic rocks to the ordinary trap with which they are closely associated. This last was but partly successful, as will appear from the following preliminary notes.

Occurrence of the Nepheline Syenite and Associated Rocks.

Brookville is a small village on the Delaware, in the southwestern part of Hunterdon County, and is readily reached from Trenton by the Belvidere Division of the Pennsylvania Railroad. The nearest towns of importance are Lambertville, about $2\frac{1}{2}$ miles down the river, and Stockton, about a mile upstream. As shown by the State geological map of New Jersey, the village lies almost in the middle of the broad belt of the so-called Triassic, or Newark formation, which occupies so prominent a place in the geology of the State. On the same map there is indicated the relatively small trap-mass of Mt. Gilboa, just east of Brookville, in connection with which occur the rocks which are presently to be described. It is thus seen that the nepheline syenite of Brookville occurs nearly 60 miles a little west of south from the well-known Beemerville locality, and in rocks of entirely different age and character. The Beemerville intrusions are in the Palæozoic rocks of what Salisbury† has called the Appalachian Zone, while the Brookville masses are in the Mesozoic rocks of the Piedmont Zone. Between these two physiographical and geological provinces lies the ancient crystalline zone of the Highlands.

* Published with the permission of the Director of the U. S. Geological Survey.

† Physical Geography of New Jersey, Geol. Surv. of N. J., vol. v, 1895, pp. 5-6.

For a general account of the geological relations of the Mt. Gilboa trap and the surrounding sediments, the reader is re-

1.



ferred to a recent paper by Kümmel.* A word or two, however, may not be out of place in explanation of the accompanying sketch-map (fig. 1.), which is taken from the Lambertville topographic sheet of the U. S. Geological Survey. For the general geological data I am indebted to Mr. Darton, and to the paper by Kümmel already mentioned.

The Mt. Gilboa trap-mass lies between two faults—the Flemington fault on the northwest, and the Dilts Corner fault on the southeast, both of which are only partly shown on the sketch-map. In each case the rocks lying southeast of the line of dislocation are on the downthrow side of the fracture. Northwest of the Flemington fault, in New Jersey, lie the arkose sandstones and conglomerates of the Stockton series of the Newark, the beds dipping westerly. On the Pennsylvania side of the river however, Palæozoic limestone is exposed between the base of the Stockton beds and the fault-line. Southeast of the Dilts Corner fault, the soft red shales of the Brunswick series extend down the river to the trap masses below Lambertville. Between the two fault-lines the rocks consist of the dark shales of the Lockatong series, the Mt. Gilboa trap-mass, and several smaller bodies of trap, not shown on the sketch-map. The trap is regarded by Kümmel as intrusive, and his view is undoubtedly correct, for the shales just west of the main trap-mass are metamorphosed near the contact into quartz-biotite hornfels—a fine-grained crystalline aggregate of quartz, biotite and probably feldspar.

The nepheline syenite was found on the northwest edge of the main body of trap, just below the forks of a little brook which flows into the Delaware about a quarter of a mile south of Brookville. The exposure is not more than a few square yards in extent, and the contact with the ordinary fine-grained trap, which surrounds the nepheline syenite on at least three sides, was nowhere seen. Closely associated with the nepheline syenite and with the trap is a micaceous syenite, exposed in the bed of the brook just at the forks. Like the nepheline syenite, this rock is apparently limited in its occurrence to a small mass, the exact relations of which to the adjacent rocks were not discoverable in the field.

Near the southern end of the Mt. Gilboa trap-mass, just north of Barbour & Ireland's quarry, a small mass of syenitic rock occurs enclosed in the trap, but here also the exposures are inadequate to determine the exact extent of the mass and the relation which it bears to the trap.

The two localities referred to in the preceding paragraphs

* The Newark System or Red Sandstone Belt of New Jersey, Annual Rept. of the State Geologist, 1897, pp. 32, 75, 109-110, etc.; also pl. II. and fig. 9.

are indicated on the accompanying sketch-map by the two black dots near the edge of the trap area.

Microscopical Petrography.

Nepheline Syenite.—Megascopically this is a light gray granular rock of medium grain, which bears a very superficial resemblance to the nepheline syenite of Moultonboro, N. H. Dark amphibole is abundant, usually in slender prisms up to a centimeter in length. Biotite, while less abundant, is a conspicuous constituent in most hand-specimens, as it forms irregular poikilitic plates, usually about 5^{mm} in diameter. The dark minerals appear to constitute between a fourth and a third of the rock, but are not always uniformly distributed. They lie in a nearly white granular ground in which the lens reveals cleavage faces of feldspars, sometimes finely striated, and light brownish grains with greasy luster which presumably are more or less altered nepheline.

The microscope shows the rock to have a hypidiomorphic-granular structure and to consist of alkali feldspar >nepheline (including its alteration products) >< amphibole > biotite > cancrinite >< soda-lime feldspar > muscovite >< ægirine-augite > apatite, titanite, and fluorite. Iron ore is almost lacking, although a few grains of magnetite occur included in, or close to, the amphibole. Analcite, usually filling triangular spaces between the feldspars, is rather abundant in some sections. It is probably wholly secondary. Sericite is present as a decomposition product of the feldspars. Calcite occurs somewhat irregularly, usually associated with the analcite. The latter is also accompanied at times by small amounts of a fibrous mineral which is probably natrolite.

All the feldspars show a gray turbidity similar to that which is so common a feature of the syenitic rocks of Norway and elsewhere. Partly on this account, but more by reason of their lack of crystal outline and their confused intercrystallization, specific determination of the feldspars by optical means is not always possible. Individual grains of orthoclase pass indistinctly and irregularly into micropertthitic patches or are intricately intergrown with a feldspar showing fine albite lamellæ—probably anorthoclase. This latter is often partly automorphic with reference to the orthoclase and micropertthite. One area, with fine, shadowy micropertthitic structure, showed distinct cleavage traces, probably basal, and the emergence of a bisectrix. The extinction referred to this cleavage was about 12°, which would seem to indicate the presence of soda orthoclase. A small part of the twinned feldspar may be albite or acid oligoclase. In general the feldspars show the lack of optical homo-

geneity and the indefinite patchy intergrowths frequently observed in syenitic rocks containing considerable amounts of both potash and soda.

The nepheline originally occupied areas between the feldspars, often of triangular form, but it is almost wholly decomposed and replaced by fine aggregates of secondary products, or by transparent areas of analcite. The aggregates are usually too fine to allow of the microscopic determination of their component minerals. In many cases however they consist chiefly of a sericitic mica (possibly paragonite) and analcite, the latter forming a matrix in which the minute mica scales lie.

The amphibole, which is black in the hand-specimens, agrees in its optical character with the hornblende common in many nepheline syenites.* It occurs in prisms more or less automorphic in the prism zone. The optical orientation is the usual one $a = a$, $b = b$, and $c \wedge c =$ about 9° . The pleochroism is a greenish yellow, b brown or dark green, and c dark brownish green. The absorption is $b > c > a$. The amphibole is not optically homogeneous, a single crystal frequently showing considerable variation in color and pleochroism. It is often intergrown with biotite, the latter commonly forming an outer fringe or border to the amphibole. More rarely it is intergrown with a pyroxene which is apparently an ægirine-augite; but the latter mineral is never abundant, and is wholly wanting in some thin sections.

The biotite possesses no features of special interest beyond a tendency toward poikilitic structure and frequent intergrowths with amphibole.

Cancrinite, with its relatively strong double refraction, is a rather conspicuous constituent in some thin-sections when viewed with crossed nicols. It is clear and colorless, and occurs in irregular areas or in forms partly idiomorphic in the prism zone. It is found sometimes in little nests associated with calcite and analcite, or completely filling interstices between the feldspars, or even embedded in the latter. The prismatic cleavage is marked by fine straight lines, and the extinction is parallel. Sections approximately normal to the prism axis give a negative uniaxial interference figure. The index of refraction is distinctly lower than the balsam. The interference colors are more brilliant than those of the other minerals in the thin sections, with the exception of the muscovite. However they rarely exceed blue of the first order, and are usually orange. Confusion with muscovite is sometimes possible in a hasty examination, but the differences in

* Rosenbusch, *Massige Gesteine*, 1896, p. 158.

the refractive indices, in the double refraction, and in the optical orientation with reference to the cleavage, readily serve to distinguish the two minerals. The cancrinite may be in part secondary, but there is no direct evidence that it is not all primary.

Muscovite (including sericite), on the other hand, is for the most part plainly secondary in this rock, and forms a considerable part of the fine-grained aggregates which now represent the nepheline. It occurs also as a decomposition product of the feldspars. One or two larger plates of muscovite were noted, however, which may be of primary origin. As it is not practicable to distinguish optically between muscovite and paragonite in such an occurrence, the possible presence of the soda mica should not be lost sight of.

Analcite is revealed in the thin-sections as clear colorless isotropic areas, usually occupying more or less triangular spaces between the feldspars. The index of refraction is considerably below that of the balsam. The mineral is traversed by irregular cracks but shows no cleavage. It is sometimes associated with small amounts of a colorless, radially fibrous mineral which appears to be natrolite. Both minerals gelatinize readily and completely in hydrochloric acid. The analcite, as previously noted, also occurs as fine aggregates with white mica.

Apatite is a moderately abundant accessory in slender prisms up to a millimeter in length. Titanite occurs in small crystals and grains but is not abundant. Fluorite occurs sporadically in nests with calcite and analcite and is easily recognized by its pale lilac color. It is without much doubt secondary. Iron ore is almost wanting, and is practically restricted to a few grains of magnetite near, or included in, the amphibole.

A chemical analysis of the nepheline syenite, made by Mr. George Steiger of the U. S. Geological Survey, is given below. He was unable to detect any carbonic acid, and for this reason the optical properties of the mineral determined as cancrinite are given with some detail in the preceding petrographic description. It will be seen that the analysis is otherwise perfectly normal for a nepheline syenite relatively rich in soda. For comparison there is placed under II an analysis of the Red Hill nepheline syenite, which is higher in silica and lower in alumina, but otherwise agrees fairly well with the Brookville rock. The analysis of the Beemerville nepheline syenite is given under III, not so much on account of its resemblance to the Brookville rock, as to exhibit the contrast, particularly in the alkalies, in the compositions of these two New Jersey occurrences, which might have been expected to show more agreement.

Chemical Analyses.

	I.	II.	III.
SiO ₂	54.68	59.01	53.56
TiO ₂ .....	.79	.81	----
Al ₂ O ₃	21.63	18.18	24.43
Fe ₂ O ₃	2.22	1.63	2.19
FeO	2.00	3.65	1.22
MnO	trace	.03	.10
CaO	2.86	2.40	1.24
SrO	----	trace	----
BaO .....	.05	.08	----
MgO	1.25	1.05	.31
Li ₂ O	----	trace	----
K ₂ O	4.58	5.34	9.50
Na ₂ O	7.03	7.03	6.48
Water at 100° C. ..	.27	.15	} .93
“ above 100° C. ..	1.88	.50	
Cl	none	----	----
F .....	.22	----	----
SO ₃ .....	.07	----	----
CO ₂	none	.12	----
P ₂ O ₅ .....	.28	trace	----
	<hr/>	<hr/>	<hr/>
	99.81	99.98	99.96
Less O .....	.09		

99.72

- I. Nepheline syenite from Brookville, N. J. Geo. Steiger, analyst.
- II. Nepheline syenite from Red Hill, Moultonboro, N. H. Described by Bayley, Bull. Geol. Soc. Am., vol. iii, p. 231. W. F. Hillebrand, analyst.
- III. Nepheline syenite from Beemerville, N. J., Bull. 148, U. S. Geol. Surv., p. 80. L. G. Eakins, analyst.

Mica Syenite.—This is a gray, medium granular rock which has been described as occurring at the fork of the Brook, close to the nepheline syenite. The hand-specimens show abundant biotite, apparently some amphibole or pyroxene, and both white and pinkish feldspars. The pinkish feldspar is somewhat unevenly distributed and shows a tendency to gather in small, ill-defined, vein-like segregations or streaks. Under the microscope the rock shows a hypidiomorphic-granular structure and is seen to consist of alkali-feldspar > biotite > pale green diopside-like pyroxene. The accessory minerals are apatite and iron ore. There is also considerable secondary chlorite, calcite, and sericite. The feldspars are generally turbid and partly decomposed to sericitic aggregates. They show the irregular mottling and fine indefinite twinning common in the

alkali feldspars containing both soda and potash molecules. There is probably a little acid oligoclase present with the other feldspars. The biotite is in the main fairly fresh, but is sometimes partly chloritized. It occurs in short stout prisms or thick scales, giving abundant oblong sections with somewhat ragged ends.

The pyroxene is largely altered to calcite and chlorite. It shows a tendency toward idiomorphic form and the larger crystals frequently have a pale pinkish interior with a greenish rim, both being optically continuous. In some specimens no pyroxene is recognizable, and in others there is present a green amphibole which may exceed the pyroxene in amount. The rock generally shows considerable alteration, which renders its petrographic study unsatisfactory.

Hornblende Syenite.—This rock, which occurs, as already described, near the southern end of the trap-mass, just north of Barbour & Ireland's quarry, is a coarse-grained and slightly microlitic aggregate of flesh-colored feldspars and rather bleached-looking fibrous green amphibole. The feldspar and amphibole both show a tendency toward prismatic development, and some cleavage faces of the former are seen under the lens to be finely striated. The microscope reveals a hypidiomorphic-granular aggregate of alkali feldspar, amphibole, and a little quartz. The alkali-feldspar is turbid with the usual brown dust-like particles, and is besides usually full of wisps of secondary sericite. Nearly all the feldspar shows fine polysynthetic twinning, corresponding to both the albite and pericline laws. But the twinning is often very irregular, occupying only a portion of an individual grain, and is sometimes associated with fine microperthitic intergrowths. Some acid soda-lime feldspar (oligoclase) may possibly be present, but the bulk of the feldspar is probably an alkali-feldspar identical with, or closely related to, anorthoclase. The index of refraction is in all cases lower than the balsam. The abundant secondary sericite, and absence of calcite, suggest that the lime molecule must occupy a very subordinate position in the composition of the feldspars.

The amphibole is pale yellowish green, and occurs in allotriomorphic areas between the feldspars. In a few instances the amphibole is compact, but it usually shows a distinct fibrous structure, each area being made up of bundles of numerous slender prisms, not all of which are in parallel orientation. The pleochroism is a pale yellowish green, b dark yellowish green, and c pale green. The absorption is $b > c > a$. The optical scheme is the usual one $a = a$, $b = b$, and $c \wedge c =$ at least 16° . Quartz occurs in subordinate amount as irregular clear grains between the feldspars. It contains fluid cavities

with an occasional movable bubble, and capillary crystals of rutile (?) Apatite in stout colorless prisms is a fairly abundant accessory constituent. Titanite occurs as idiomorphic crystals, but more commonly as rounded or irregular grains. There is a little iron ore present, usually associated with the amphibole areas.

Hornblende Granite.—The specimen described under this head was supposed, when collected, to be merely a fresher facies of the hornblende syenite, as its richness in quartz was not apparent in the hand-specimen. It appeared in the field to form a part of the same small mass in the trap which afforded the specimens of syenite just described. It is a medium granular, dark gray rock, in which the feldspars are brownish in color, and show a tendency toward prismatic development in the direction of the edge $p \wedge m$. The dark constituent, apparently dark green hornblende, is fairly abundant in rather irregular prisms. A little dark mica is also visible in the hand-specimen. Under the microscope partly idiomorphic sections of decomposed feldspar and irregular plates of amphibole lie in a sort of groundmass composed of quartz and feldspar micropegmatically intergrown. The idiomorphic feldspars appear to be, in part at least, an acid oligoclase, but many of them are completely changed into very fine sericitic aggregates. The hornblende is the common green variety and presents no unusual features. The most striking thing about the thin-section is the beautiful manner in which the quartz and feldspar, together constituting more than half the rock, are intergrown. The feldspar of these intergrowths is rendered turbid by numerous brownish dust-like particles, and its character is not easily determined by optical means alone. It is, however, without much doubt an alkali feldspar closely related to soda orthoclase or to anorthoclase, although it may be in part ordinary orthoclase. It shows occasionally the fine irregular twinning and lack of optical homogeneity which characterize anorthoclase. The quartz is always more or less intergrown with feldspar, but sometimes shows homogeneous patches of considerable size.

The Trap-rock.—The intrusive mass forming Mt. Gilboa is fairly uniform throughout. It is commonly a dark gray rock of fine to medium grain, and the structure, as visible to the eye, is granular. A typical specimen collected by Mr. Darton from near the center of the area shows under the microscope a hypidiomorphic-granular structure, and is a fairly fresh aggregate of labradorite (ab, an_4) > augite > hypersthene > quartz > biotite < iron ore. It is a fine-grained gabbro in which a brown diallagic augite is intergrown with subordinate amounts of hypersthene and biotite. The quartz was the last mineral

to crystallize, and is very subordinate in amount. It is sometimes micropegmatitically intergrown with a small amount of a dusty alkali feldspar; probably orthoclase. The hypersthene is not always present, and its place is sometimes taken by hornblende, as in a specimen from Barbour & Ireland's quarry. The structure on the whole is granular rather than ophitic, and the name gabbro is an appropriate designation for the trap-rock as a whole.

The Relation of the Syenitic Rocks to the Gabbro.

No evidence was detected, either in the field or through microscopical investigation, which in any way supports the hypothesis that the alkali-rich rocks are differentiated facies of, or immediately derived from the body of magma which cooled as gabbroitic trap. The former are distinctly different from the trap which surrounds them, and transitional facies appear to be wholly lacking. The trap as a whole shows rather striking uniformity wherever studied. Specimens, wherever collected, are characteristically trap-like, and afford no suggestion of such extreme differentiation as would be necessary for the production of a nepheline syenite, a mica syenite, or a hornblende granite. The syenitic masses, therefore, are either small dike-like intrusions in the trap, or else they are inclusions in the latter, floated up from some unknown terrane below, through which the trap broke. The exposures were not sufficiently good to determine which of these hypotheses is the true one. That the masses are dikes, would seem to be most inherently probable. Yet dikes might be expected to show more linear persistency than could here be detected, although the exposures were poor and the time given to their examination somewhat brief. On the whole it seems most likely, in this case, that the masses are included fragments, caught up in the trap magma at the time of its intrusion. It must be admitted, however, that the question of their origin is still an open one, which further work, with other and better exposures, may answer.

Washington, D. C., June, 1899.

ART. XLIX.—*The Fauna of the Magellanian Beds of Punta Arenas, Chile*; by Dr. A. E. ORTMANN.

By the term "Magellanian beds" the writer designates the new Tertiary horizons* discovered by Mr. J. B. Hatcher near Punta Arenas, and described in a previous article.† The introduction of this term seems to be the more appropriate, since the stratigraphical position of these beds, and their relation to the Patagonian beds, is known, and since they differ in their paleontological character from all other deposits found in Patagonia. For the present, the writer intends to use this term only for the *marine* beds, underlying the Punta Arenas coal, that is to say, for horizons II and III of the paper quoted.

Since these beds reveal the true geological position of the Punta Arenas coal (between the Magellanian and Patagonian beds), and since there seems to prevail, as regards the age of this coal or lignite, quite an uncertainty‡, it is well to give a more detailed report on this "Magellanian" fauna, in order that it may be recognized, if found elsewhere. Since it is, however, impossible at present, to give a complete account of this fauna, and since an elaborate description illustrated by figures of the new species is at present impossible, the writer has decided to publish as soon as possible a short preliminary report on the species of marine fossils recognized in these beds, taking pains to characterize the new forms as exactly as possible chiefly by comparing them with well known species. The final report on these and other invertebrate fossils collected by Mr. Hatcher in Patagonia will be forthcoming in due time.

Ostrea torresi Philippi (Die tertiären und quartären Versteinerungen Chiles, 1887, p. 215, pl. 48, f. 8).

Magellanian beds, upper division (horizon III). Numerous specimens (21 lower, 14 upper valves).

* Ameghino (Synopsis Geologico-Paleontologica, Suplemento, 1899, p. 12) has tried to correlate the Punta Arenas section with the Patagonian deposits, and considers the horizons here under discussion (II and III) as belonging partly to the Upper Patagonian beds (piso leonense) and partly to the transitional beds between the Patagonian and Suprapatagonian. It is, however, impossible for me to regard a deposit as Patagonian that does not contain a single Patagonian fossil. The so-called "piso leonense" (upper part of Patagonian), with an entirely different fauna, which has not been described, is not represented in Mr. Hatcher's collections, although the latter come from all imaginable horizons within the Patagonian-Suprapatagonian series.

† This Journal, December, 1898.

‡ Compare O. Nordenskjöld, Svenska Exped. till Magellansländerna, Bd. 1, No. 2, 1898, p. 19 and 23, 24; P. Dusen, *ibid.*, No. 4 (Ueber die tertiäre Flora der Magellansländer, 1899, p. 4).

Agreeing well with Philippi's figure. Characterized by the radial folds, which in our specimens—although they are much water-worn—are well exhibited. In all the other Patagonian oysters these radial folds are only faintly or not at all developed.

Recorded by Philippi from the Straits of Magellan.

Cardita elegantoides spec. nov.

Magellanian beds, upper part.—3 isolated right valves, 2 valves imbedded in the matrix.

Shell somewhat rounded, slightly inclined, with 19 radial ribs, which are rounded, about as broad as the intervening furrows, and nodulose. Lunula small, oblong. L. 16^{mm}, H. 14^{mm}.

This species comes very near in outline to *C. elegans* Lmck. (see: Wood, Eoc. Biv. Engl. 1, 1861, p. 146, pl. 22, f. 16) from the upper Eocene of England and France. Also the number of ribs agrees closely (17–20 in elegans): but there is a broader interspace between the ribs in *C. elegans*, and the ribs themselves are thinner and more nodulous.—*C. volekmanni* Philippi (l. c., p. 173, pl. 37, f. 4) from Tubul (Navidad beds) is also closely related, but has only 15 ribs.

Venus difficilis spec. nov.

Magellanian beds, upper part.—1 left and 2 right valves.—Lower part (horizon II).—2 double valves and 2 left valves.

Shell thick, oblique, inflated, posteriorly a little narrowed, apex situated in advance of or at $\frac{1}{4}$ of the length. Area long, occupying almost the whole of the posterior dorsal margin of the shell. Lunula oval, flat, exterior surface with close and regular concentric furrows, and with some concentric lines of growth (remains of ventral margins), the latter more crowded near the lower margin, and irregular. Concentric furrows sharp, not interrupted, $\frac{1}{2}$ —1^{mm} distant from each other. Length of a large valve: 75^{mm}, height 64^{mm}, transverse diameter (of half shell) 18^{mm}. Apex situated at 16^{mm} from anterior end.

Comes very near to *V. subsulcata* Philippi (p. 115, pl. 17, f. 7), from the Cretaceous of Algarrobo, but in the latter species the concentric furrows do not extend all over the surface, but are interrupted in the middle.

Venus arenosa spec. nov.

Magellanian beds, upper part.—3 right valves.

Shell transversely elliptical, moderately swollen. Posterior end hardly narrower than the anterior. Apex situated at ca. $\frac{1}{3}$ of the length. Area indistinct, shorter than the posterior part of the dorsal margin. Nymphae $\frac{2}{3}$ — $\frac{3}{4}$ as long as the area. Lunula indistinct. Exterior surface with strong concentric lines of growth, which have between them finer concentric striae (obliterated in our specimens on account of the closely adhering matrix). L. 60^{mm}, H. 44^{mm}, D. (half shell) 15^{mm}. All three specimens show the hinge teeth of a true *Venus*.

Characterized by the elongate form, and allied by that character to *V. landbecki* Philippi (p. 116, pl. 20, f. 8), Cretaceous, Algarrobo. The present species differs from *landbecki* by the situation of the apex, which is in the latter at $\frac{2}{7}$; the former is less swollen, and the area is indistinct.

Cytherea (?) *pseudocrassa* spec. nov.

Magellanian beds, upper part.—1 right valve.

Shell very thick and very convex, outline almost circular, posterior end rounded. Apex at $\frac{2}{7}$ of the length. Exterior surface concentrically striated, but the adhering matrix obscures the sculpture. L. 62^{mm}, H. 60^{mm}, D. 25.

The generic position is doubtful. Posterior tooth of the hinge divided. Ventral margin of shell not crenulated.

Characterized by the very thick shell and the almost circular outline, *V. crassa* Phil. (p. 128, pl. 21, f. 1), from the Pliocene Coquimbo beds of Chile, is related, but in our species the transverse diameter is greater, the hinge is different, and the apex is situated differently. Further, *V. alta* Phil. (p. 116, pl. 20, f. 3), from the Cretaceous of Algarrobo is an allied form, but the present species is higher, and rounded posteriorly (not "subrostrate"): *V. alta* is more triangular in outline.

Dosinia complanata (Phil.) (Artemis c. Philippi, l. c., p. 114, pl. 15, f. 1).

Magellanian beds, lower part. 4 left, 3 right valves, imbedded in matrix.

I cannot distinguish our specimens from Philippi's species.

This form has been found previously in the Navidad beds near Matanzas, Chile.

Glycimeris ibari (Phil.) (Panopæa i, Philippi, l. c., p. 167, pl. 35, f. 4).

Magellanian beds, lower part. 1 double valve, 4 left and 2 right valves.

Characterized by the elongate outline, arcuate ventral margin, narrower posterior end, and situation of apex.

Recorded from Magellanes and Skyring Water.

Glycimeris subsymmetrica spec. nov.

Magellanian beds, upper part.—1 right valve.

Almost identical with *G. ibari*, but not so much elongated, and posterior end not narrowed. Relation of H. to L. = 1 : 1, 6 (in *ibari* = 1 : 1, 8 to 2, 0).

Lutraria undatoides spec. nov.

Magellanian beds, lower part.—1 double valve.

Shell almost elliptic, $1\frac{1}{2}$ as long as high. Surface with strong and somewhat irregular, undulated concentric folds. Dorsal margin almost straight, ventral margin slightly arcuate. Apex at $\frac{1}{3}$ of the length, prominent, rather sharp, incurved. Anterior and posterior ends evenly rounded off and of the same height. L. 32^{mm}, H. 21^{mm}, apex at 11^{mm} from anterior end.

A remote resemblance exists to *L. undata* Phil. (p. 164, pl. 33, f. 8-11), from Tubul and Lebu (Navidad beds), but our species is very much shorter.

Patella pygmaea spec. nov.

Magellanian beds, upper part.—1 specimen.

Shell subconical, low, outline regularly oval. Apex situated in the anterior half. Surface with fine, crowded, a little unequal, radial ribs, crossed by concentric lines of growth, and finely granulated. L. 7^{mm}, B. 5^{mm}, H. 4^{mm}.

The position of this species may be with the genus *Acmaea*, as the thinness of the shell and the delicateness of the ribs suggest. At any rate, it is the first Patelloid shell found in Tertiary deposits of Patagonia.

Trochus philippii spec. nov.

Magellanian beds, upper part.—2 specimens.

Shell low, conical, not umbilicated. Whorls almost flat, only very slightly convex. Last whorl on the periphery of the base sharply angular, above this angular ridge there are 4 revolving ribs. Lower surface slightly convex, with 5 strong, revolving ribs, the most exterior separated from peripheral ridge by a broad space. Ribs of the lower surface with regular, strong granules; similar granules seem to have been present on the upper part of the whorls. H. 7^{mm}, diameter at the base: 11^{mm}.

Umbilical region closely agreeing with *T. monilifer* Lmck. from the Eocene of England and France, also the sculpture is of the same type. But *T. monilifer* is much higher, and the number of the revolving ribs is different.—*T. macsporrani* and *T. fricki* of Philippi, from the Navidad beds, are related, but different.

Turritella exigua spec. nov.

Magellanian beds, lower part.—Very abundant, numerous specimens.

Shell small, with 10 whorls, ca. 4 times as high as broad at the base. Suture deep, whorls convex, with 5-7 spiral ribs, which are rather crowded and often alternately stronger and weaker. The stronger ribs sometimes appear to be slightly granulated. H. 15^{mm}, D. ca. 4^{mm}.

Characterized by the small size, and convex whorls. The two small species of *Turritella* described by Philippi from the Navidad beds (*trilirata* and *parvula*) are easily distinguished by the flat whorls and small number of ribs.

Trochita merriami nom. nov. (= *T. costellata* Philippi, l. c., p. 93, pl. 11, f. 4, 1887, and Ortmann, this Journal, December, 1898, p. 480).*

* Non *T. costellata* Conrad (1855 Pacific R. R. Rep., v. 7, p. 195, pl. 7, f. 3). Mr. J. C. Merriam of Berkely, Cal. has called my attention to the fact, that the specific name *costellata* has been preoccupied by Conrad for a species from the Miocene of California.

Magellanian beds, upper part, 1 specimen.—Lower part, 2 specimens.

Characterized by the fine radial striae of the shell.

Recorded from Lebu, Navidad beds.

Natica chiloënsis Phil. (l. c., p. 89, pl. 10, f. 12).

Magellanian beds, upper part, 2 poor specimens.—Lower part, abundant, many specimens.

This species is to be recognized by the thick and solid shell of a more or less ovate shape, with thick callus of the inner lip, which leaves a small, narrow slit open at the umbilicus.

Recorded from the island of Chiloë, Navidad beds.

Struthiolaria hatcheri spec. nov.

Magellanian beds, lower part.—8 specimens.

Closely allied to *S. ornata* var. *densestriata* v. Ihering (Rev. Mus. Paulista, v. 2, 1897, p. 292, f. 15) from the Patagonian beds. *S. densestriata* and the present form possess on the lower part of the last whorl a number of revolving ribs of equal strength, in which character both differ from *S. ornata* Sow. In *S. hatcheri*, however, the number of the ribs of the last whorl is much higher, 20–22, than in *S. densestriata* (13); 14–15 of these ribs are placed below the series of nodules found in the upper part of the whorl. Further, *S. hatcheri* is distinguished from the other form by the suture, which is not channel-like, as in *densestriata*, but simply rectangular. By this character it approaches *S. chilensis* Phil. (= *ameghinovi* v. Ih.), but in the latter species the suture is still less deep. H. 22^{mm}, D. 13^{mm}.

Actaeon chilensis Phil. (l. c., p. 111, pl. 13, f. 16).

Magellanian beds, lower part.—1 specimen.

Agrees well with Philippi's species.

Recorded from Navidad and Matanzas.

Bulla remondi Phil. (l. c., p. 109, pl. 13, f. 7).

Magellanian beds, lower part.—6 specimens.

The figure of Philippi does not agree with the measurements given in the text, the latter being almost identical with those of Sowerby's *B. cosmophila*.

Our specimens agree with the figure of Philippi. The measurements are: H. 13^{mm}, D. 5^{mm}, relation, 1: 2, 6 (Philippi's figure: H. 21, D. 8, rel. 1: 2, 6; Philippi's text: H. 19, D. 9, rel. 1: 2, 1; Sowerby's *cosmophila*: H. 24, D. 11, rel. 1: 2, 2).

Recorded from the Navidad beds of Chile, and doubtfully (see Moericke, N. Jahrb. Min. etc., Beil. 10, 1896, p. 594), from the Cretaceous beds of Chile.

In conclusion I should like to make a few further remarks on the Punta Arenas section. This section has been mentioned

previously*), and Mr. Hatcher's account agrees fairly well with it, with the only exception that the uppermost fossiliferous bed (horizon V) has not been noticed by Nordenskjöld. In my previous report I have shown that this uppermost horizon agrees palaeontologically with the Suprapatagonian beds, true Patagonian beds being wanting here. This question has been settled in the meantime by Mr. Hatcher. He informs me, that in his opinion, there is no difference at all between Patagonian and Suprapatagonian deposits, both being only different *facies* of one and the same series of deposits. The Suprapatagonian facies is brought about by a prevailing sandy nature of the deposit, while in the Patagonian there is a more or less considerable admixture of calcareous matter. It is true, the Suprapatagonian facies is chiefly (but not always) developed near the top, the Patagonian near the base of the series, but between base and top these facies frequently interlock, giving sometimes the appearance of a discontinuity, which really does not exist. According to Mr. Hatcher there is no discontinuity between Patagonian and Suprapatagonian beds, as Ameghino maintains; in fact, he found it absolutely impossible to draw a line between these two deposits. Mr. Hatcher reached this conclusion by an examination of the contact of both deposits near Mt. Observation, and at numerous other places.

This fact confirms the opinion of the writer of the identity of both deposits formed some time ago, after the examination of the palaeontological material at hand, and the comparison of it with v. Ihering's records (after Ameghino) of the stratigraphical position of the respective fossils.

Further, this fact explains the lack of Patagonian beds in the Punta Arenas section: if Suprapatagonian and Patagonian beds are only different facies of one and the same series of deposits, they are practically identical; and it is quite clear that one may replace the other completely in certain localities; and this is exactly what we observe in the Punta Arenas section: the Patagonian beds are represented there not by the Patagonian, but by the Suprapatagonian "facies."

Princeton University, October 11.

* See Nordenskjöld, l. c., 1898, p. 24, footnote. A section of this locality has been described as early as in 1873 by Mallard & Fuchs (*Ann. des Mines*, ser. 7, v. 3, p. 97), but this represents only deposits *above* the coal. Mallard & Fuchs mention the occurrence of a large oyster and a *Pectunculus* in the *lower* part of their section, while two such fossils in association are found only in the uppermost horizon (V) of Mr. Hatcher's profile. Thus this section seems to begin where Mr. Hatcher's ends.

ART. L.—*Some of the results of the International Cloud Work for the United States*;* by Professor FRANK H. BIGELOW.

THE general scheme of the survey of the clouds proposed by the International Cloud Commission is so widely understood, that it will not be necessary to describe it again, beyond saying that the observations undertaken by the U. S. Weather Bureau began on May 1, 1896, and ended on June 30, 1897, employing one primary base station at Washington, D. C., and 14 nephoscope stations distributed quite uniformly throughout the territory east of the Rocky Mountains. The computation of the resulting data and the arrangement for the publication follow closely the prescribed forms submitted in the circulars of the commission, and while the labor of preparation up to this point was considerable, there would be nothing of special interest to say regarding that portion of the report, the whole of which will form Part VI of the Report of the Chief of Weather Bureau for 1898.

The possession of much new data, contained in the 6,600 single theodolite observations and in the 25,000 nephoscope observations, afforded, however, a favorable opportunity for considering several of the fundamental problems of Meteorology, especially in view of the fact that they develop in the most perfect manner on the North American continent, and therefore, the discussion of the observations has been pushed far beyond the limits implied in the scheme of the commission. It will be admitted, no doubt, by all those who are conversant with the true state of meteorology, that in spite of much good work on the part of able investigators, there are still serious gaps in the series of facts needed to construct a sound theory of the history of cyclones and anti-cyclones; and, furthermore, that the existing theories are neither in agreement among themselves nor with all the known facts. It was important, therefore, to develop the facts regarding the circulation of the atmosphere without bias *ab initio*; and it was essential to so far correlate the existing mathematical analyses that their true meaning as to one another and as to the results of the observations should appear. Meteorology must always remain, not a crude branch of science as some writers erroneously maintain, but a difficult one, on account of the complications attending the physical processes and the fluid motions in the complex form presented by the atmosphere. We have attempted to show how some of the apparent obstacles can be overcome by employing the methods used in these observations and reductions, and the results are such as to stimulate students to continued efforts to finally resolve these interesting problems.

* Published by permission of the Chief of the United States Weather Bureau.

A Standard System of Constants and Formulæ.

Part of the difficulty in making students generally realize that meteorological mathematics already stands upon a definite fundamental basis is due to the fact that while many papers of great merit exist, they are detached from one another, and there is no well defined system of formulæ which is common to all such related investigations. Professor Ferrel's treatises, it is true, in spite of his inattention to a consistent and clear notation, cover the ground, as he conceived the solution of the problem in a consecutive order from beginning to end. Yet many of his primary developments are exceedingly complicated; other valuable mathematical analyses have been discovered since his day; his main theory of the local cyclone has been found to be loaded with objections, so that students have expected that before long improvements would be introduced. The German school of authors, including Guldberg and Mohn, Oberbeck, Sprung, Hann and others, have followed substantially one line of thought which is characteristic of them, and though they reach many results in agreement with Ferrel's, especially in regard to the general cyclone covering a hemisphere of the earth, they have in reality radically different conceptions regarding the structure of the local cyclone. Thus, in Ferrel's case, it was assumed that the general and the local cyclone are examples of the same type of circulation, wherein the inner and the outer region of the cyclone are separated by a region where the gyratory velocity about the central axis is reduced to zero, having a positive direction inside and a negative direction outside in the lower strata, with a complete reversal as to gradient and direction in the upper strata, the entire system embracing the same fluid material in a continuous motion. The German school, on the other hand, began with the principle of the logarithmic potential, of which a common example is found in the motion of the ether as an electric current through a wire which is surrounded by a magnetic whirl. In this case there is no reversal of the direction of the gyratory motion, but instead of being a minimum at the boundary of the inner and the outer regions, it is there a maximum. The inner region is distinguished from the outer, however, by the fact that it alone has a vertical motion. This is evidently an entirely different type of local cyclone from Ferrel's. In the case of the general cyclone the American and the German schools are in much closer accord. Furthermore, some important difficulties arose from the attempt to account for the energy expended in the local cyclone, on the theory of a vertical convection due to the buoyancy of air expanded by the liberation of latent heat in large quantities

upon the condensation of aqueous vapor into water. Also, some observations discussed by Dr. Hann seemed to show that the distribution of the temperature in the upper strata of cyclones and anticyclones is not consistent with the principles of the vertical convectional theory. Since there exists this lack of harmony as to the main theory of the motions of the atmosphere, it is no wonder that progress has been very slow in reducing meteorology to a strictly scientific basis on its theoretical side. Accompanying this confusion in the theory; the authors have seldom been fortunate enough to adopt the same notation for their mathematical discussions, so that the study of this subject has been unusually wearisome to all those who have had no strong motive for undertaking such work.

It seemed to me, therefore, desirable to construct a standard system of equations covering the entire subject, and to transcribe the most important papers into that system, at least to such an extent that a student would have but little trouble in following the writings of one author and comparing the others, by means of this exposition. Several original solutions covering important ground have been introduced, with the object of bringing the formulæ into practical working forms. These include the development of the equations of motion in rectangular, cylindrical, and polar coördinates, the treatment of the humidity term in the barometric formulæ, the transformation of the thermodynamic equations in the stages represented by the α , β , γ , δ , processes in the formation of clouds, and in the treatment of the equation of continuity by which the vertical component of motion is connected with the horizontal in the case of the local cyclone. A complete new series of tables, adapted to practical work, was computed from these sets of formulæ, and applied throughout the discussion of the cloud observations.

The Weather Bureau Tables.

As a basis for the construction of the new tables, a system of the constants employed in meteorology was selected, and many of the immediate minor relations defined by suitable brief formulæ, the entire set showing numerous useful cross connections between the several parts. The primary constants are substantially those adopted by the International Committee, and they are so arranged in parallel columns for the Metric and the English systems as to be convenient for reference; the logarithms of the numbers are also given. Many minor problems in meteorology, which are often obscure in a wordy exposition, are readily explained by means of these defining formulæ, since these are more definite than any general explanation.

In preparing to discuss the physical processes which occur in the several cloud strata at heights ranging from the surface to

an elevation of at least 15,000 meters, wherein the pressure B , the temperature t , and the vapor pressure e , pass through great changes, it was found that the existing tables were wholly inadequate for the purpose. The International and the Smithsonian Barometric Tables extend only to 2,000 meters, but the new tables are computed in metric measures from 0 to 15,000 meters, and for temperatures ranging from -40° C. to $+40^{\circ}$ C. for $h = 0$ to 5,000 meters, from -50° to $+30^{\circ}$ for $h = 5,000$ to 10,000 meters, and from -60° to $+20^{\circ}$ for $h = 10,000$ to 15,000 meters; similar tables have been made in English measures up to 10,000 feet, which is sufficient for our weather map reductions. There are certain practical difficulties with the existing tables in other particulars. The formula employed by them is of the form, $B_0 - B = B(10^m - 1)$, where $B_0 > B$, and m is a function of the temperature, humidity, gravity, altitude, and surface topography. It gives the correction which, added to the pressure B at a given altitude, will reduce it to B_0 , the pressure at sea level. It is perceived that this is a very special case of reduction, namely, downward to sea level, whereas in cloud work we must be prepared to reduce upward as well as downward, and also where neither pressure is that at sea level. If by the above formulæ we wish to reduce upward, it must be done through approximations, because the value of B at the upper station is involved in the formula, and not the value of B_0 with which we begin. There is trouble with the humidity term, especially in the Smithsonian tables, where a certain average value of the vapor pressure is included permanently within the m , so that the humidity does not stand out by itself, and is, therefore, not available for an independent discussion. But in cloud work this is the very element most required, and it is not proper to assume either an invariable law of variation of the vapor contents, nor, as in the International tables, is it possible to measure the humidity term at the top and bottom of a column which is not in contact with the ground. For example, in reducing from the bottom to the top of a cumulus cloud, I have taken the following form of equation,

$$\log. B_0 = \log. B + m - \beta m - \gamma m,$$

where m includes the temperature, the altitude, and the topographic terms, β the humidity and γ the gravity. What is wanted is the value of B_0 , and not the correction $B_0 - B$, which involves one superfluous operation in computing. The humidity term with its assumed law of vertical variation, and the gravity term here stand out distinctly by themselves, and the whole subject of humidity is easily open to treatment, and even to employing a different law without disturbing the main term, which is limited to the dry air pressures. By simple

transformation the formula is available for reduction upwards; this may take place between any two fixed points whatsoever; the set of special tables to determine the heights by the barometric pressure is dispensed with entirely, since the m table is arranged for double entry with the arguments, h = height, t = temperature; with h, t, m . any two being given, the other follows. These new tables give identical results with the others for special cases; they work rapidly in practice; one can compute with accuracy to the one-thousandth of a millimeter, so far as the data are concerned.

The second important group of tables contains the four thermodynamic processes, which take place in the formation of clouds, the unsaturated, the saturated, the freezing and the frozen stages, designated as the $\alpha, \beta, \gamma, \delta$, stages, respectively. This subject has been discussed by Ferrel, Hann, Lord Kelvin and others along one line, and by Hertz and von Bezold along another line, though both came to the same conclusion so far as the results are concerned. Hertz has constructed a diagram which graphically deals with the four stages, but it was necessary for him to neglect in part the vapor contents, so that although the divergence is no more than 7^{mm} of pressure between the rigorous and the approximate solutions, yet all the fine accuracy which should pertain to good cloud computations is sacrificed. The direct application of the rigorous formulæ, which are very complex, would require an excessive amount of labor to use them, and they are never utilized by meteorologists. But it seemed to me essential to overcome this obstacle, and accordingly the formulæ were transformed so as

to depend upon three arguments, namely, $B, t, \frac{e}{B}$. pressure, temperature, and the ratio of the vapor pressure to the barometric pressure. The tables are simple in structure, and involve only moderate interpolations. They work rapidly and have proven to be perfectly satisfactory by use in the actual reductions. The results of this discussion have led to much definite information regarding the physics of clouds in many connections, but only a few of them can be mentioned here.

(1) In the case of air rising from the lower strata to form cumulus clouds there exists a definite level at which saturation takes place, namely the base of the cloud. It is necessary to clearly distinguish between true adiabatic saturation, and the saturation as it takes place in the actual atmosphere. The formulæ of the tables as they stand deal only with adiabatic processes, but in order to apply them to the atmosphere the value of the ratio $\frac{e}{B}$ must be observed at the base of the

cumulus cloud. In the adiabatic process the ratio $\frac{e}{B}$ is constant in the unsaturated stage, that is from the ground to the cloud base, and by two or three easy approximations, after starting with B, t, e at the ground, we compute B_s, t_s, e_s and the height h_s of saturation. Now the question is, does this computed height h_s agree with the measured height of the cumulus base h_i ? The result of our work is to show that the observed height h_i is greater than h_s . We must, therefore, determine the values B_i, t_i, e_i at the base of the cloud accurately, and thus find the relation between the adiabatic $\frac{e}{B}$ and the actual $\frac{e_i}{B_i}$. A considerable number of kite ascensions were made in the summer of 1898 by the Weather Bureau, and more than 100 cases occurred in which the B_k, t_k, e_k, h_k were measured by the kite instruments on entering the base of the cloud. These have enabled us to study this important question carefully. It may be stated that four distinct ways have been developed of finding the temperature quite approximately at the cloud base, and hence the vapor tension and the pressure, so that for usual conditions, that is to say excepting the strongly stratified condition which occurs when currents of very different temperatures flow over one another, we can compute the pressure at the height of a mile with an error usually of ± 0.02 and always of less than ± 0.04 inch, which insures good map drawing at that height. The determination of the divergence of the actual from the adiabatic atmosphere is valuable in its application to several meteorological problems.

(2) It has been assumed that the value of the ratio $\frac{e_i}{B_i}$ obtained for the base of the cumulus cloud holds true throughout the cloud itself, and that in this space the adiabatic laws prevail. The theodolite measurements give the height of the top of the cloud where the process of saturation ends. The saturated or β stage has two cases for consideration, the first being where the top of the cloud is lower than the beginning of the freezing stage, and the second where it passes into or through that stage. We computed the B', t', e', h' at the top of the cloud in the first case, but the corresponding B_0, t_0, e_0, h_0 at the bottom of the freezing or γ stage in the second case. Then the thickness of the γ stage with the value of B^0, t^0, e^0, h^0 at the top of it followed, these being the same as $B_{11}, t_{11}, e_{11}, h_{11}$ at the bottom of the frozen or δ stage. Finally with the observed h'' , the top of the cloud, B'', t'', e'' were computed. This gives the heights at which the several stages begin and end, and hence the thickness of each stage; thence the gradients of

B.t.e. per 100 meters in each stage were computed and tabulated. The work was so arranged as to deal with the mean normal meteorological elements prevailing in each of the 12 months, so that the annual variations in all these quantities were found. Also selected cases, as of the towering cumulo-nimbus clouds, some of which reach to 14,000 meters, were computed throughout. The details are so instructive that several of the computations are reproduced in full. The tops of the lofty cumulo-nimbus give a temperature of -30° or -40° C. in several cases, and of -59° C. in one high cloud. This method of computing the temperature at the top of lofty clouds is a welcome addition to the method of the balloon ascensions for determining the meteorological elements in the highest strata, since the clouds may be considered as accurate sounding gauges. The mean heights of the stages show that the γ stage begins at about $\frac{e}{B'} = 0.0090$ and develops as a wedge-shaped space up to a thickness of about 500 meters for $\frac{e'}{B'} = 0.0300$. In this the hail forms, and especially in summer when t, e, h_i have large values. I am inclined to think that the stratified appearance of hail stones is due to the fall through a series of these γ spaces alternating with warmer β stages, which may form at different heights in the congested state of the atmosphere accompanying thunder storms, rather than to any vertical orbital circulation such as Ferrel suggested. At every point of these computations the checks are so perfect that we can work accurately to 1 millimeter of pressure and to 0.1° C. temperature, when the trial approximations are repeated two or three times.

(3) It is a most interesting problem to determine just how much heat must be added to an ideal adiabatic atmosphere to produce the actual atmosphere in the several levels. Two preliminary discussions were required to develop this subject. The first was to determine the normal distribution of temperature as observed each month at all altitudes up to 16,000 meters. For this purpose all the available results of balloon ascensions were collected and discussed by tabular and graphic methods, involving a balanced network of mutually dependent lines, by which the average temperature topography was made up to that elevation. Upon the reliability of these observations and this method of treatment the accuracy of the results required must depend. The second discussion was the determination of the mean heights of the several types of clouds from the stratus to the cirrus in each month of the year. This was found by means of the theodolite observations at Washington, D. C., and from them the region covered annually by each

kind of cloud was carefully mapped out. Beginning with the mean meteorological elements *B.t.e.* at the surface for each month, purely adiabatic values were computed at the required heights; and then the actual state of the atmosphere was computed by using the temperatures derived from the balloon ascensions. Subtracting these values at the same heights, the difference is the quantity of heat required. In integrating $\int \frac{dQ}{T_m}$ I was obliged in this preliminary work to regard T_m as constant, and to take as its value the mean of the adiabatic and the observed temperatures. The formula employed is,

$$\int dQ = Q = T_m \left[\begin{aligned} & \left(.2374 + .1512 \frac{e}{B} + .0232 \frac{e^2}{B^2} \right) \log T - \left(.06858 + .02592 \frac{e}{B} \right) \log B \\ & - \left(.2374 + .1512 \frac{e}{B} + .0232 \frac{e^2}{B^2} \right) \log T_0 + \left(.06858 + .02592 \frac{e}{B} \right) \log B_0 \end{aligned} \right]$$

the upper terms being the observed and the latter adiabatic. In computing, the dry air and the vapor terms for temperature and for pressure, four in all, were carried through separately; finally the values for each 1000-meter level were interpolated, so that we have in a table the calories required to effect the change from an adiabatic to the actual atmosphere. This is at least a fair effort to elucidate quantitatively the problem of the absorption of heat by the earth's atmosphere. Its interest and importance would justify a special campaign of operations devoted to its more careful study.

The Motions of the Atmosphere.

Besides these mathematical discussions and physical researches, a considerable portion of our labor was expended upon the determination of the stream lines and vectors of motion, which occur throughout anti-cyclonic and cyclonic regions in the United States. The complexity of this subject is so great that it is necessary to refer the reader to the charts of the Report itself for a complete presentation of the result. We had two sources of information to depend upon, namely, the long series of cloud charts which are used in the daily forecasts, but are not published, and the nephoscope observations of the International cloud year. These charts contain blue arrows, showing the direction of motion of the lower or cumulus clouds, and red arrows giving the direction of the upper or cirrus clouds. The United States was divided by me into six areas, the northern Rocky Mountain region, the Lake region, the New England districts, the southern Rocky Mountain region, the west Gulf States and the south Atlantic States, for the purpose of discussion. Then for high and low areas

respectively in each district, for winter and also for summer, a set of composite charts was constructed by placing a transparent sheet of paper over a series of the maps, selected to show the same weather type for each district, and tracing in the arrows, from which finally a set of resultant vectors for equal squares was computed by counting the number of compass point directions thus recorded. From 40 to 70 maps were used in making each chart, and the resulting vectors were reduced to an average of 40 vectors in each square. If the frequency of direction is proportional to the prevailing movement of the air, then we obtain a chart of relative motions in all parts of the high and low areas. The result is most instructive, in many respects, of which a few are mentioned. The wind and the lower cloud circulation up to the strato-cumulus type are quite the same in form, though the cloud level is rather more rounded; this movement is very independent of the upper cloud region, which is due eastward, or only a little sinuous over the highs and lows. This is true of ordinary cyclones, but in the case of hurricanes for the South Atlantic States the penetration of the lower circulation into the higher is very pronounced, showing a much deeper disturbance of the air. Cyclones are very thin, only 2 or 3 miles deep, while hurricanes are certainly 5 or 6 miles deep. The anticyclonic and cyclonic areas are hardly to be considered as centers of motion except in the very lowest strata, since currents of air blow directly across them from west to east, even in the cumulus region of the Rocky Mountain districts. It is shown that remarkably long streams of air, as from the North Pacific to the Lake region, and from the Gulf of Mexico to the Lake region, counterflow against each to form the cyclonic circulations. We cannot consider these to be due to vertical convections drawing in these distant masses of air by indraft, since the vertical component ceases at 2 or 3 miles high. Rather the great horizontal convections of the lower strata, caused by the interchange of air between the polar and the tropic zones, produce counter currents at the cyclone centers, which develop vortices discharging upward into the permanent eastward drift. The study of these normal charts of circulation will tend to correct some prevailing erroneous conceptions regarding the structure of cyclones. It will surprise many to see that a strong and warm current in the cumulus region blows directly from the Pacific Ocean eastward across a cold-wave area, showing that cold waves are thin masses of air, hardly one mile thick, produced by surface radiation on the eastern or lea side of the mountains. It is no less remarkable to find that the center of the high areas formed by the isobars drawn from reductions made by the Hazen method, now employed by the Weather Bureau, is often 500 miles distant

from that indicated by the vectors of motion. The discrepancy between gradients and wind directions in the mountain districts is already well known, but the problem acquires a special interest from the study of these new charts.

The discussion of the nephoscope observations was very laborious in consequence of the necessity of handling the large mass of figures several times. For this purpose, the area surrounding a center of motion was subdivided into 20 parts, symmetrically disposed on three circles about the center, so that the transference from rectangular to cylindrical coordinates should be simple. The right hand (anti-clockwise) rotation, with positive direction "as the arrow flies," was also adopted. Each observation was located in the proper sub-area according to its own district; each cloud type, at a given mean height, was computed separately; the northern districts were compiled by themselves and the southern by themselves; mean resultants for the vectors were found for each sub-area in 8 levels, and charts of the circulation were constructed by accurately plotting in these vectors. The result shows that a slightly sinuous eastward movement prevails over the high and low areas in the cirrus stratum, gradually deepening as the surface is approached, till in the strato-cumulus the gyratory movement is very marked, and in the cumulus, stratus and wind levels predominant. The actual velocities diminish from ± 10 meters per second in the cirrus to 5 or 6 m. p. s. at the surface. Next on the theory that the sinuous motion is due to components in composition, the mean rectangular N-S and W-E components were found algebraically, subtracted from the total vectors and the residuals were combined in a secondary system of vectors, which were also transferred to charts. These are the true local gyratory vectors as distinguished from the general motions on the hemisphere. In the cyclone they show an inward radial component from the *bottom to the top*, and nothing outward in the upper strata, as Ferrel's circulation requires. They do not show a maximum velocity at a certain distance from the center with falling off nearer it, as Oberbeck's solution demands, but they increase from the outside up to the center. The components are strongest in the strato-cumulus region and diminish above and below; they show a continuous inflow everywhere together with a strong rotation about the center, such as to cause a true vortex with discharge upwards throughout, the forced upflow being injected into the eastward drift which carries it off, while at the same time the flow is somewhat deflected anti-clockwise. In the anticyclone on the two outer circles 750 and 1250 k. m. radius, there is outflow from top to bottom on all sides; near the center there is inflow at the top, reversal at the middle, and outflow at the bottom, thus causing reversal of gradients in the

interior of the anticyclone. The entire system of high and low areas seems to be constructed by the counterflow, chiefly in the cumulus and strato-cumulus levels, of long currents due to horizontal convection, the double action on the pressure, that is the formation of high and low pressures simultaneously in adjacent districts, being referred to the general circulation of the atmosphere, especially the deflecting and centrifugal forces, rather than to local temperature accumulations. The North American Continent is the region where cyclones *form* in large numbers, and Europe-Asia the region where they *dissipate*, so that the violent general circulation over the United States in the lower strata, as compared to that of Europe, is chiefly responsible for this excess in the production, near or in the United States, of the local storms of the northern hemisphere.

A careful study of these vectors in all strata up to 11,000 meters, 7 miles high, reveals the very important fact that there is little disposition to conform to the canal theory of the circulation over the hemisphere, as ordinarily taught, namely consisting of a southward movement in the lower strata from the polar zone towards the tropics, with reversal of the component from east to west at latitude 35° , together with an overflow northward in the higher strata from the tropics towards the poles. While the general circulation conforms to this type in many features, there has always been the greatest difficulty in accounting for the comparatively slow eastward drift in the upper strata of the higher latitudes. Ferrel attributed a large part of the required retardation to the effect of friction, but this is in reality a comparatively small term. Also he stated that the difference in the eastward velocity of the northward and southward moving strata at different elevations represented the expenditure of retardational energy. As a matter of fact the lower strata do not move southward *as a whole*, and our observations do not indicate that the higher strata are vigorously moving northward, because that component is very small. What takes place is this: in each stratum from the surface to the cirrus level about as much air moves north as south, for there are enormous counter currents *passing by each other at the same level, and not over one another at different elevations*. This puts a new aspect on the entire problem of the general circulation. It looks as if the solar radiant energy was absorbed chiefly in the lower strata, and that instead of going the rounds, overflowing above from the tropics, there is developed a continuous leakage in the lower strata, which is observed as our persistent winds from the south. These meet the north winds which flow in obedience to the general circulation, as figured by the form of the land and ocean areas. This escape from the tropical belt diminishes the pressure in low latitudes,

which would require to be balanced by an excessively rapid eastward drift. Furthermore, the formation of cyclonic vortices discharging into the eastward drift and distorting it, also retards the eastward velocity. It is along these lines that a more probable explanation of the existing moderate eastward motion may be found than in the Ferrel theory, which has been widely accepted by students.

There is a chapter treating of the barometric diurnal wave and its relation to the magnetic diurnal vectors, as developed in Bulletin No. 21, 1898, together with a comparison of the diurnal components of the motion of the atmosphere locally, which shows some interesting relations. I have been unable, in the time at my disposal, to utilize the new general tables of motion in connection with the vectors just described. Something has been done in the way of a theory of the local cyclone and the tornado, which is promising, though its completion must be postponed to a future day. I have been most efficiently assisted in this work by the faithful labor of Messrs. H. H. Kimball, H. L. Heiskell and R. H. Dean, who have taken great interest in the observations and the computations. The Chief of the Weather Bureau has always placed at our disposal all the resources of the office, and the other officials have uniformly rendered all the aid in their power.

ART. LI.—*The Bacillaria of the Occidental Sea*; by
ARTHUR M. EDWARDS, M.D., F.L.S.

IN studying the bacillaria of the Western Coast of North America I have gathered knowledge of them from Alaska to Washington through Oregon to California and into Mexico. In Alaska I have not specimens as yet, but I have them from British America and so down. I have also specimens of bacillaria from the region of the Great Plain of Fremont, which I have called the Occidental Sea in my paper published in this Journal for 1891. This extends on the east side of the Rocky Mountains several hundreds of miles, even to the coast of California, where it includes the islands which are Anacapa, Catalina and other islands. For I have bacillaria identical with those on the Great Plain itself, and extends into British America and south into Mexico.

Why it is a sea and not a lake can be judged when I state that it extends at least one thousand miles from north to south, and the same distance from east to west, a larger piece of water than is seen at the present day anywhere, except the Atlantic, Pacific and Indian Oceans. But this sea contained fresh water, as I will show. The boundaries of it are uncertain of course, but they extend, as I have just said, beyond the coast in California away to several hundred miles east of the Rocky Mountains and to the north into British America and south into Mexico. It was formed in what is known as the Eocene period, for this reason: C. King in Vol. I of the Report of the Geological Explorations of the Fortieth Parallel, Washington, 1878, in the Recapitulation of Tertiary Lakes, page 444, gives nine lakes as appearing in the Eocene, Miocene and Pliocene periods. In the Eocene there are, in order, Ute Lake, which takes in the Vermilion Creek group of King and the Wahsatch group of Hayden, which filled the entire Green River Basin for a distance of one hundred and fifty miles, with an east and west expansion of about the same on the 40th parallel. In New Mexico it has been discovered by Marsh and farther south it extended, but how far is uncertain. The deposits belong to the basal Eocene on the borders of the Cretaceous. We can understand why Hector places the marine deposits of New Zealand in the Cretaceous now, although I have several fresh water deposits from that section of country which are found below the marine strata. The deposits of the lake are the beds of the Vermilion Creek group, a series having in the field of the 40th parallel a maximum thickness of 5,000 feet "and carrying besides abundant fresh water mollusca and a few fishes, the characteristic vertebrata fauna of the lowest Eocene." (King,

page 486.) The rocks are red sandstones almost vermilion in color, whence the name of the creek, which is a branch of the Green River and of that of the Colorado. So it can be understood why the sea emptied into the south and also why the red sandstone is there without the white bacillarian clay upon it. For the same phenomenon is present in Lake Passaic in New Jersey, where the clayey sand without bacillaria in it is present at Logansville and Pleasant Plains in parallel thin layers, the bacillarian clay having lower specific gravity, being carried down to a lower point and deposited at Hatfield Swamp when the ice barrier melted at and about Paterson.

Next came what King calls the Gosiate Lake, which includes the Green River group of Hayden and the Elka group of King. Along the east base of the Wahsatch Mountains the rocks were tilted up to 14° , leaving the Uinta River, as it was in the Lake period, an island. The rocks in this were mere shales and calcareous clay, with some white fine limestone. Numerous fishes and insects and abundance of fresh water molluscs of the genera *Viviparus*, *Goniobasis* and *Unio*, besides a few beds of lignite, are seen.

Then came the Wahsachie Lake, which includes the Bridges group of King and the Uinta Lake, which includes the Uinta group of Emmons and Marsh. This ends the Eocene. Afterwards the Miocene was laid down, which, in the province of Nevada and Oregon contains the Pah-Ute Lake, which was the Truckee group of King and the John Day group of Marsh, and was contemporaneous with the Sioux Lake, which in the province of the Great Plains includes the White River group of Hayden. The Miocene came also to an end and was followed by the Pliocene: In this came, contemporaneous with the province of the Great Basin, North Park Lake of the North Park group of Hague and Hayden and Cheyenne Lake of the province of the Great Plains and the Niobrara group of Marsh.

At Kausoh Mountains in Nevada the strata were as follows:

1. Basalt	
2. Coarse, sandy grit	30 to 40 ft.
3. Saccharoidal cream-colored limestone carrying fresh water fossils	} 60 ft.
4. Marly grits	
5. Finely-grained friable sandstone	70 ft.
6. Formation concealed by Quaternary accumulations	100 ft.
7. Marly grit	50 to 60 ft.
8. Infusorial silica	200 ft.
9. Tufa, base not exposed	250 ft.

In the saccharoidal cream-colored limestone are shells of mollusca over the infusorial silica.

Although specimens from this immediate locality have not been examined by me, yet I have some from near by. They are the following, and I have to thank the U. S. Geological Survey for them.

BEAVER LAKE BEDS, BEAVER VALLEY, NEVADA.

<i>Amphora ovalis</i> F. T. K.	<i>Melosira undulata</i> F. T. K.
<i>Cocconeis placentula</i> C. G. E.	<i>Navicula brebisonii</i> F. T. K.
<i>Cymbella lanceolata</i> C. G. E.	“ <i>elliptica</i> F. T. K.
<i>Denticula thermalis</i> F. T. K.	“ <i>oblongea</i> F. T. K.
<i>Encyonema caespitosum</i> F. T. K.	“ <i>sphaerophora</i> F. T. K.
<i>Fragilaria capitulum</i> D.	<i>Nitzschia sigmoidea</i> C. G. E.
<i>Gomphonema olivaceum</i> F. T. K.	<i>Stephanodiscus carconiensis</i>
“ <i>vitrium</i> C. G. E.	C. G. E.

TRUCKEE RIVER NEAR WADSWORTH, NEVADA.

<i>Cocconeis placentula</i> C. G. E.	<i>Melosira orichalcea</i> F. T. K.
<i>Cyclotella operculata</i> C. A. A.	

THREE MILES S. OF HELENS SPRINGS, NEVADA.

<i>Epithema jurgensii</i> C. A. A.	<i>Navicula sphaerophora</i> F. T. K.
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THREE MILES S. OF HELENS SPRINGS, NEVADA.

<i>Eunotia gracilis</i> C. G. E.	Crystals of calcium carbonate.
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TRUCKEE RIVER S. NR. W. OF WADSWORTH, NEVADA.

Crystals of calcium carbonate.

INDIAN RESERVATION, BANKS OF TRUCKEE RIVER, NEVADA.

<i>Amphora ovalis</i> F. T. K.	<i>Fragilaria (Staurosira) pinnata</i>
<i>Cocconeis lineata</i> C. G. E.	C. G. E.
“ <i>pediculus</i> C. G. E.	<i>Gomphonema intricatum</i>
“ <i>placentula</i> C. G. E.	F. T. K.
<i>Cyclotella (Stephanodiscus) ber-</i>	<i>Gomphonema mamilla</i> C. G. E.
<i>olinensis</i> C. G. E.	<i>Hantzschia amphioxys</i> C. G. E.
<i>Cymatopleura elliptica</i> A. B.	<i>Melosira undulata</i> F. T. K.
“ <i>solea</i> A. B.	<i>Navicula amphicephala</i> C. G. E.
<i>Cymbella gastroides</i> F. T. K.	“ <i>bacillum</i> C. G. E.
“ <i>lanceolata</i> C. G. E.	“ <i>maculata</i> C. G. E.
“ <i>maculata</i> F. T. K.	“ <i>sphaerophora</i> F. T. K.
<i>Encyonema ventricosum</i> F. T. K.	“ <i>undula</i> C. G. E.
<i>Fragilaria (Staurosira) pectin-</i>	“ <i>varians</i> C. G. E.
<i>alis</i> F. C. L. N.	<i>Roicosphaenia curvata</i> F. T. K.
	<i>Surirella striatula</i> T.

PLAYA BEDS IN CAÑON, SOUTH END OF CARSON LAKE.

<i>Amphora ovalis</i> F. T. K.	<i>Navicula cuspidata</i> F. T. K.
<i>Cocconeis placentula</i> C. G. E.	forma <i>Craticule</i> .
<i>Cymbella cymbiformis</i> C. G. E.	<i>Navicula elliptica</i> F. T. K.
" <i>lanceolata</i> C. G. E.	" <i>sphaerophora</i> F. T. K.
<i>Cyclotella operculata</i> C. A. A.	" <i>viridis</i> C. G. E.
<i>Epithemia jurgensii</i> C. A. A.	<i>Roicosphaenia curvata</i> F. T. K.
<i>Gomphonema intricatum</i> F. T. K.	<i>Surirella ovata</i> F. T. K.
	" " var <i>Utahensis</i> A. G.

WALKER RIVER ASSOCIATED WITH FOSSIL BONES.

<i>Epithemia gibba</i> C. G. E.	<i>Navicula viridis</i> C. G. E.
<i>Eunotia arcus</i> C. G. E.	" <i>veneta</i> F. T. K.
<i>Gomphonema olivaceum</i> C. G. E.	<i>Nitzschia linearis</i> C. A. A.

MUD FLAT TWO M. S. OF OLDER CREEK VALLEY, HOT SPRINGS.

<i>Melosira crenulata</i> F. T. K.	<i>Navicula viridis</i> C. G. E.
<i>Navicula acrosphaeria</i> C. G. E.	

This looks volcanic. It is light, fawn-colored and finely comminuted.

LOWER LAKE BEDS, RASH CREEK SECTION, MONO LAKE, CALIFORNIA.

<i>Cocconeis placentula</i> C. G. E.	<i>Navicula borealis</i> C. G. E.
<i>Navicula cuspidata</i> F. T. K.	" <i>sphaerophora</i> F. T. K.
forma <i>oraticulare</i> .	<i>Surirella ovata</i> F. T. K.

FOUR M. N. OF WADSWORTH LOWER SPECIMEN FOR "WINTER SECTION."

<i>Cyclotella operculata</i> C. A. A.	<i>Navicula</i> (<i>Amphipora</i>) <i>Navicularis</i> C. G. E.
<i>Melosira crenulata</i> F. T. K.	<i>Navicula viridis</i> C. G. E.

WHITE TERRACE, MARBLE BUTTE, NEVADA.

<i>Amphora ovalis</i> F. T. K.	<i>Navicula sphaerophora</i> F. T. K.
<i>Cocconeis placentula</i> C. G. E.	" <i>rheinhardtii</i> A. G.
<i>Epithemia jurgensii</i> C. A. A.	<i>Stephanodiscus berolinensis</i> C. G. E.
<i>Cymatoplea solea</i> A. B.	
<i>Cymbella gastroides</i> F. T. K.	<i>Surirella ovata</i> F. T. K.
<i>Encyonema ventricosum</i> F. T. K.	" <i>striatula</i> F. T. K.

WHITE TERRACE, PYRAMID LAKE, NEVADA.

<i>Cocconeis placentula</i> C. G. E.	<i>Gomphonema intricatum</i> F. T. K.
<i>Cyclotella operculata</i> C. A. A.	
<i>Cymbella parva</i> W. S.	<i>Melosira undulata</i> F. T. K.
<i>Epithemia jurgensii</i> C. A. A.	" <i>crenulata</i> F. T. K.
	<i>Roicosphaenia curvata</i> F. T. K.

WHITE BEDS NEAR FIRST POINT ON THE N. SHORE OF SODA
LAKE.

Melosira crenulata F. T. K.

Crystals of calcium carbonate. Pieces of hornblende.

LAKE BED IN EXPOSURE NEAR LEWIS SYMONDS RANCH, MONO
LAKE, CALIFORNIA.

Denticula thermalis F. T. K. *Synedra ulna* P. A. C. N.

The rest is sand.

LOWER LAKE BEDS, RUSH CREEK SECTION, MONO LAKE,
CALIFORNIA.

Cocconeis placentula C. G. E. *Navicula borealis* C. G. E.
Navicula cuspidata F. T. K. " *sphaerophora* F. T. K.
forma *oraticulare*. *Surirella ovata* F. T. K.

Also two which contained no fossils of any kind.

UPPER LAKE, BEDS S. SHORE OF MONO LAKE, CALIFORNIA.
LAKE BONNEVILLE, UTAH.

It will be observed that crystals of calcium carbonate are found in several specimens. These have been deposited when the water which formed the Occidental Sea evaporated, and sodium carbonate is also formed later thrown down as in the soil that is left and in the soda springs which are common all over the Great Plain. Sodium chloride and sodium biborate (borax) are common in waters of the Great Salt Lake, Utah, and Borax Lake, California.

It will be noticed that the forms of the bacillaria are not the same in the specimen as in another. But this is the rule of their distribution. How different are the forms in one spring from another only a few feet apart and in fact in one specimen taken from a river from another taken nearby. The forms can never be the same everywhere in a deposit. That is local distribution.

It will be interesting to note what C. King says of the Eocene lake in the United States Exploration of the Fortieth Parallel, vol. I, 1878. He says on page 360, "As yet the great Eocene lake, whose main deposits are circumscribed by the boundaries of the basin of the Colorado River, is the only one of any considerable geographical area known in the middle Cordillera region. In its earlier stages this lake was coextensive with the rocks of the Vermilion Creek Period, the lowest division of the American lacustrine Eocene." It will be seen that King places the lake in the lowest Eocene where it merges into the Cretaceous, and that he does not make the lake much larger than the Vermilion Creek Period, but this was only on the Fortieth Parallel. He does not take into consideration Mono Lake in California, or the Staked Plain of Texas. These I do, as also Cash Lake in California and other places. Thus I extend the

Eocene Lake into a sea; for its size entitles it to the name of the Occidental Sea.

And now I wish in this connection to say why I place the Subplutonic before the Miocene. That is to say, the Eocene is the Subplutonic which I formerly published. In the opening I shall have to explain why I use the terms Subplutonic and Miocene strata instead of the newer Eocene and Neocene for these layers which I describe before going into the occurrence of one before the other, as I shall thereafter do, and the Subplutonic first. This term I used to designate layers of Diatomaceæ, as they were then called, when I first described them, now about thirty years ago. When I come to study the deposits of Diatomaceæ which were placed in my hands by Mr. George Gibbs, the Geologist of the Northwest Boundary Survey, there were found certain specimens which were associated with eruptions of lava and constituted vast fields on the Columbia River (which were well known) and elsewhere. The lava was always in layers, as was the diatomaceous earth, and they were seen to be distinct from the well known Monterey strata, which had been placed in the Miocene Tertiary by Blake, Bailey and Ehrenberg, and also distinct from the recent strata, which were common everywhere. They were designated Subplutonic, being found beneath lava. This name was given to them not from geological reasons, for their geological position was not found, and the geology of the country where they occurred had not been then discovered. How or when the lava appeared was not ascertained then and was undetermined. These were fresh water strata, or at least the Diatomaceæ were known to inhabit lake and fresh water, and did not grow in brackish marshes or on the shore of the salt ocean.

The Miocene Tertiary, on the contrary, were known from analogy to be marine. That is to say, they contained the same Diatomaceæ which grew in the ocean along the shore on rocks now. They were called Miocene Tertiary, and Blake supposed them to be analogous to the Richmond, Virginia, stratum, which was discovered by Rogers and placed by him in the Miocene Tertiary. And this was supposed to be the same as certain formations in Europe which Lyell had placed there. This was found, as we shall see, not to be so. The Miocene and Pliocene were studied by Dall and Harris and published in the U. S. Geological Survey correlation papers, in 1892. They found the strata in the United States were not exactly analogous or contemporaneous with the Miocene and Pliocene in Europe, or did not contain the same Mollusca, and therefore they erected a period to contain them. They called it the Neocene. So the Richmond, Virginia, and Monterey, California, were marked as the Neocene or Miocene Tertiary strata. They belong to a period which is recent, as I now think.

Newark, N. J.

ART. LII.—*On the Volumetric Estimation of Cerium*; by
PHILIP E. BROWNING.

[Contributions from the Kent Chemical Laboratory of Yale University—XC.]

SOME forty years ago Bunsen* showed that the oxide obtained by the ignition of cerium oxalate might be estimated volumetrically by bringing it in contact with potassium iodide and strong hydrochloric acid and determining the iodine set free. This method may be briefly described by a translation of part of the original article: "The substance to be determined is weighed out in a glass flask of from ten to fifteen cubic centimeters capacity, a few crystals of potassium iodide are added, and the neck of the flask is drawn out by the aid of a blowpipe to a narrow opening. The flask is filled almost to the narrowing of the neck with hydrochloric acid which is free from chlorine or iron chloride, and a little sodium carbonate is added in order to displace the last trace of air by carbon dioxide. The flask is then closed by sealing off the neck in the blowpipe and warmed in a water bath until the cerium compound is completely dissolved, and the quantity of iodine set free is determined by iodometric analysis."

The anhydrous dioxide prepared by the ignition of the oxalate or hydroxide is very slowly acted on by acids, especially when pure.† For this reason the method which Bunsen described has remained the only one adapted to the satisfactory volumetric estimation of the ignited dioxide.

Two portions of the dioxide were prepared by treating the crude cerium chloride in concentrated solution with gaseous hydrochloric acid‡ to saturation to remove the iron. The cerium chloride was then dissolved in water, potassium hydroxide added in excess and chlorine gas passed until the precipitate became distinctly orange in color and the solution gave a strong odor of chlorine.§ This operation was repeated until a portion of the precipitate dissolved in acid showed no didymium absorption bands when examined before the spectroscope. The whole precipitate of the dioxide was then dissolved in hydrochloric acid and the oxalate precipitated by ammonium oxalate in large excess. The precipitated oxalate was then washed thoroughly with hot water until the washings gave no test for hydrochloric or oxalic acids and ignited to the dioxide. Another portion of the dioxide was later prepared by precipitating a solution of pure cerium chloride by means

* *Annalen d. Chem. u. Phar.*, cv, 49.† Rose: *Handbuch der Analytischen Chemie*, Band i, 219.‡ Dennis and Magee: *Zeitschr. f. Anorgan. Chem.*, iii, 260.§ Mosander: *Phil. Mag.*, xxviii, 241; Dennis: *Zeit. f. Anorgan. Chem.*, vii, 252.

of ammonium oxalate, washing and igniting as described. The dioxide in all three cases was of a light chamois color, and uniform results were obtained from the three portions.

A modification of the method of Bunsen—(with G. A. HANFORD and F. J. HALL).

Weighed portions of the pure cerium dioxide were placed in small glass stoppered bottles of about 100^{cm}³ capacity, together with a gram of potassium iodide free from iodate and a few drops of water to dissolve the iodide. A current of carbon dioxide was passed into the bottle for about five minutes to expel the air, 10^{cm}³ of pure strong hydrochloric acid were added, the stopper inserted and the bottle heated gently upon a steam radiator for about one hour until the dioxide dissolved completely and the iodine was set free. After cooling the bottle, to prevent loss of iodine upon removing the stopper, the contents were carefully washed into about 400^{cm}³ of water and titrated with standard sodium thiosulphate to determine the amount of iodine liberated according to the well known reaction



A few blank determinations were carried through in the bottles without the presence of the cerium dioxide to determine the amount of iodine set free under these conditions. The amount obtained was uniformly equal to 0.04^{cm}³ of the $\frac{1}{10}$ N iodine solution which was taken as the correction and applied to all the determinations. The results follow in Table I.

TABLE I.

	CeO ₂ taken. gram.	CeO ₂ found. gram.	Error. gram.
(1)	0.1000	0.0994	0.0006—
(2)	0.1032	0.1034	0.0002+
(3)	0.1016	0.1017	0.0001+
(4)	0.1054	0.1041	0.0013—
(5)	0.2010	0.2021	0.0011+
(6)	0.1104	0.1109	0.0005+
(7)	0.1914	0.1907	0.0007—
(8)	0.1604	0.1603	0.0001—
(9)	0.2146	0.2145	0.0001—
(10)	0.1108	0.1099	0.0009—
(11)	0.1346	0.1347	0.0001+
(12)	0.1540	0.1534	0.0006—
(13)	0.1976	0.1968	0.0008—
(14)	0.1230	0.1240	0.0010+
(15)	0.1199	0.1201	0.0003+
(16)	0.1524	0.1528	0.0004+
(17)	0.1212	0.1211	0.0001—
(18)	0.1528	0.1543	0.0015+

In order to obtain a further check upon the accuracy of the method, portions of the cerium dioxide were weighed out and placed in a distillation apparatus previously employed for similar purposes and described in former articles from this laboratory, viz: a Voit flask, serving as a retort, sealed to the inlet tube of a Drexel wash-bottle, used as a receiver, the outlet tube of which was trapped by sealing on Will and Varrentrapp absorption bulbs. In the retort the cerium dioxide together with 15^{cm}³ of water, 1 gram of potassium iodide and 10^{cm}³ of pure strong hydrochloric acid were placed. In the receiver were 100^{cm}³ of water and 2 to 3 grams of potassium iodide, and in the bulbs a dilute solution of potassium iodide. Before adding the hydrochloric acid a current of carbon dioxide was passed through the apparatus for some minutes. After adding the acid, the liquid was boiled in the current of carbon dioxide* to a volume of 15^{cm}³, when the free iodine had almost completely left the retort and passed into the receiver, and the apparatus was allowed to cool.

The iodine in the receiver was titrated directly with sodium thiosulphate, and that in the retort after dilution of the residue to about 400^{cm}³, the later amount seldom exceeding the equivalent of a few drops of $\frac{1}{10}$ N iodine solution.

The results follow in Table II.

Here also blank determinations were made but no correction was found to be necessary.

An attempt early in the work to titrate by an alkaline arsenite the iodine liberated, after neutralizing the hydrochloric acid, brought out some curious results which seem worthy of mention.

TABLE II.

	CeO ₂ taken. gram.	CeO ₂ found. gram.	Error. gram.
(1)	0.1028	0.1013	0.0015 —
(2)	0.2060	0.2055	0.0005 —
(3)	0.2014	0.2012	0.0002 —
(4)	0.1716	0.1711	0.0005 —
(5)	0.0974	0.0972	0.0002 —
(6)	0.1600	0.1587	0.0013 —
(7)	0.1268	0.1254	0.0014 —
(8)	0.1276	0.1268	0.0008 —
(9)	0.1620	0.1612	0.0008 —
(10)	0.1016	0.1011	0.0005 —
(11)	0.1548	0.1543	0.0005 —
(12)	0.1352	0.1342	0.0010 —

* The carbon dioxide gas was furnished by a Kipp generator from marble and hydrochloric acid of one-half strength, both of which had been boiled previously to remove all air.

In these experiments the contents of the bottles after the cerium had dissolved were carefully washed into a Drexel wash bottle upon the inlet tube of which was fused a thistle tube with a stop-cock and to the outlet tube a Will and Varrentrapp absorption trap. In the trap a solution of potassium iodide was placed and through the thistle tube a saturated solution of potassium bicarbonate was added to complete neutralization of the acid. Any iodine carried mechanically by the carbon dioxide should be held by the potassium iodide solution in the trap. After neutralization the free iodine was titrated by standard arsenious oxide solution. The results appear in Table III.

TABLE III.

	CeO ₂ taken. gram.	CeO ₂ found. gram.	Error. gram.	
(1)	0.1000	0.0987	0.0013—	I
(2)	0.1005	0.0981	0.0024—	
(3)	0.1030	0.1009	0.0021—	
(4)	0.1500	0.1475	0.0025—	
(5)	0.1030	0.1005	0.0025—	II
(6)	0.1010	0.0988	0.0022—	
(7)	0.1510	0.1508	0.0002—	
(8)	0.1530	0.1485	0.0045—	
(9)	0.2045	0.2011	0.0034—	III
(10)	0.2000	0.1958	0.0042—	
(11)	0.1334	0.1302	0.0032—	
(12)	0.1354	0.1330	0.0024—	
(13)	0.1312	0.1294	0.0018—	
(14)	0.1308	0.1277	0.0031—	
(15)	0.1060	0.1042	0.0018—	
(16)	0.1602	0.1567	0.0035—	
(17)	0.1504	0.1488	0.0016—	

As will be seen by the table, an average error of about 2 per cent runs through the entire set. The natural conclusion would be that the cerium dioxide contained some impurity; but, as the first, second and third samples, very carefully prepared, gave the same results, it seemed necessary to look elsewhere for an explanation. Two possible causes suggested themselves: first, mechanical loss during the process of neutralization, and second, the possible formation, under the conditions, of iodine chloride, which if formed would in the process of neutralization probably take the form of potassium chloride, iodide, and iodate, and thus some of the originally free iodine would be withdrawn from the amount titrated. To test these theories, portions of the $\frac{1}{10}$ N iodine solution roughly equivalent to the amounts of iodine set free by 0.1 and 0.2 grms. of

CeO_2 , were drawn off into bottles previously filled with carbon dioxide, treated with the usual amount of strong hydrochloric acid (10cm^3), and after standing from thirty to forty-five minutes, neutralized and titrated as already described. The results were most interesting and seemed to show a loss of iodine closely equivalent to that shown by the results of Table III, and proportional to the amount of iodine originally present. A few determinations were carried through in the same way except that the neutralization was omitted and dilution and titration with thiosulphate substituted. These showed a loss of iodine well within the limits of such a process. The results follow in Table IV.

TABLE IV.
With Arsenious Oxide.

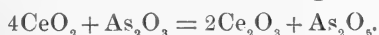
	Iodine $\frac{1}{10}$ N taken. cm^3 .	Iodine $\frac{1}{10}$ found. cm^3 .	Error. cm^3 .	Equivalent error on CeO_2 . gram.
(1)	5.22	5.07	0.15 —	0.0026 —
(2)	5.09	4.97	0.12 —	0.0021 —
(3)	5.10	4.97	0.13 —	0.0022 —
(4)	5.66	5.47	0.19 —	0.0033 —
(5)	5.10	4.97	0.13 —	0.0022 —
(6)	10.22	9.97	0.25 —	0.0043 —
(7)	10.21	9.97	0.24 —	0.0041 —

With Sodium Thiosulphate.

(1)	5.	5.01	0.01 +	0.0002 +
(2)	5.	4.99	0.01 —	0.0002 —
(3)	10.	10.02	0.02 +	0.0003 +
(4)	10.08	10.12	0.04 +	0.0007 +

The action of arsenious oxide upon Cerium Dioxide—(with W. M. D. CUTTER).

The fact that cerium dioxide is reduced by hydriodic acid suggested the possibility of the application of arsenious acid in acid solution to the same end according to the reaction



The extreme difficulty with which the ignited cerium dioxide when pure dissolves in acids has already been mentioned, and for this reason it was found practically impossible to obtain any results by this method. Weighed portions of the dioxide were placed in Erlenmeyer beakers with an excess of a solution of arsenious oxide $\frac{1}{10}$ N, 10cm^3 of (1-1) sulphuric acid were added, and the boiling continued until the fuming point of the acid was reached; but even at this point only a partial solution of the dioxide had taken place.

The dark brown powder obtained by igniting the carefully washed oxalates, precipitated in acid solution by treating a solution of crude cerium chloride with ammonium oxalate or oxalate acid, is very fairly soluble in acids. Mengel* has recently shown that this product contains a dioxide of praseodidymium which acts as does cerium dioxide toward reducing agents. This fact makes the results recorded in the treatment of this ignited mixture of oxides of no value analytically, but of interest in the comparative study of the two reducing agents, arsenious oxide and hydriodic acid. Two portions of this mixture of oxides gave the following results, which agree fairly well with those of Mengel.

	Amt. of substance taken. gram.	CeO ₂ + (PdO ₂ ?) found. gram.	Calculated on 0.1000 gram. gram.
(1)	0.1037	0.0530	0.0511
(2)	0.1034	0.0538	0.0520

The average of these results was taken as a standard —0.0515 gram. CeO₂, etc., to every 0.1000 gram. of material. Three carefully weighed portions of this same material were placed in Erlenmeyer beakers with 10^{cm}³ of $\frac{1}{10}$ N arsenious oxide solution and 10^{cm}³ of dilute (1—4) sulphuric acid and boiled until complete solution had taken place. The liquid was then cooled, neutralized with potassium bicarbonate and titrated with standardizing iodine to determine the amount of arsenious oxide remaining, and from it the amount used in the reduction of the dioxide according to the reaction given above. The results obtained follow.

	Amt. taken. gram.	Amt. CeO ₂ found. gram.	CeO ₂ calculated for 0.1000 gram. gram.
(1)	0.1005	0.0493	0.0491
(2)	0.1015	0.0494	0.0487
(3)	0.1005	0.0486	0.0484

As will be seen, the results obtained by this method fall about 0.0030 gram. below the standard as obtained by the distillation method, which seems to show that the arsenious oxide does not effect the complete reduction of the cerium dioxide from CeO₂ to Ce₂O₃.

In order to study this point a little more fully and upon the pure dioxide, definite portions of a standard solution of pure cerium chloride were precipitated by ammonia in the presence of hydrogen dioxide and boiled to reduce the CeO₂ formed to the conditions of Ce₂O₃. The precipitated hydrated dioxide was filtered off and carefully washed until the washings gave no

* Zeitschr. für Anorgan. Chem., xix, 67.

indication of hydrogen dioxide. The moist precipitate was then washed into a beaker, one gram of potassium iodide added and 10^{cm^3} of strong HCl. The precipitate dissolved quite readily in the cold and the iodine liberated was determined by standard sodium thiosulphate. The results appear in Table V.

TABLE V.

	CeO ₂ taken. gram.	CeO ₂ found. gram.	Error. gram.
(1)	0.1142	0.1140	0.0002—
(2)	0.1142	0.1147	0.0005+
(3)	0.1142	0.1152	0.0010+
(4)	0.1142	0.1159	0.0017+
(5)	0.1142	0.1152	0.0010+
(6)	0.1142	0.1156	0.0014+

Another series of these precipitates prepared in the same way was boiled with a definite amount of arsenious acid in acid solution, as previously described in the case of the ignited dioxide. The results which are recorded in Table VI show, as in the case of the ignited dioxide, an insufficient reduction of the cerium by the arsenious acid.

TABLE VI.

	CeO ₂ taken. gram.	CeO ₂ found. gram.	Error. gram.
(1)	0.0381	0.0370	0.0011—
(2)	0.0381	0.0361	0.0020—
(3)	0.1142	0.1077	0.0064—
(4)	0.1060	0.1002	0.0058—

The Estimation of Cerium Oxalate by Potassium Permanganate—
(with LEO A. LYNCH).

Stolba* has stated that cerium oxalate may be estimated volumetrically after the same manner as calcium oxalate by treating the washed precipitate, suspended in warm water, to which a moderate amount of sulphuric acid has been added, by potassium permanganate. As the titration proceeds the precipitate disappears and the end reaction is sharp. He also finds that the permanganate does not oxidize the cerium from the lower to the higher condition. So far as we have been able to discover, no experimental evidence has been presented to prove the correctness of Stolba's statement, and the work to be described was undertaken to furnish such evidence.

* Sitzungsber. d. kgl. böhm. Gesellsch. d. Wissenschaften v. 4 Juli, 1879; Zeitschr für Anal. Chem., xix, 194.

The solutions used were prepared and standardized as follows: The cerium solutions were made by dissolving 10 grams of pure cerium chloride in one liter of water, and standardized by precipitating measured and weighed portions, in a faintly acid solution, with ammonium oxalate, filtering, washing, igniting, and weighing as the dioxide (CeO_2). A solution of potassium permanganate was prepared and standardized by titration against weighed amounts of ammonium oxalate. A solution of ammonium oxalate was made and its value determined by titrating measured amounts against potassium permanganate. Definite portions of the cerium solution were drawn from a burette and after diluting with water from 100 to 200^{cm}³ a definite amount of ammonium oxalate was added, care being taken to have an excess over the amount necessary, and the whole warmed to insure a more crystalline precipitation.* The precipitate was then filtered off on paper and carefully washed, the filtrate and washings being collected in a liter Erlenmeyer flask and set aside for future use. The precipitate was treated with about 10^{cm}³ of hot (1–4) sulphuric acid, which dissolved it completely, if not at first, by running it through the filter a few times, and the solution and washings were collected in another liter flask. The total volume of liquid was made up to about 500^{cm}³, warmed to about 70° C. to 80° C. and titrated with potassium permanganate to the appearance of the faint blush of color showing the complete oxidation of the oxalic acid. The filtrate from the cerium oxalate containing the excess of oxalic acid was diluted to 500^{cm}³, acidified with 10^{cm}³ of dilute (1–4) sulphuric acid, one gram of manganous sulphate added to prevent the interfering action of the free hydrochloric acid upon the estimation of the oxalic acid,† and titrated with potassium permanganate after the same manner as the dissolved precipitate. A definite quantity of ammonium oxalate having been originally taken, it became possible, by subtracting from it the amount obtained, to derive the measure of the oxalate used in the precipitation of the cerium oxalate. By this procedure, it will be observed a check was made upon the results obtained by the titration of the precipitate. In experiments (1) to (6) the cerium oxalate was thrown down in neutral solution, in experiments (7) to (10) in acid solutions. The treatment of the filtrate in experiment (1) was made without the presence of the manganous sulphate. The results recorded in Table VII seem to uphold the statement of Stolba.

* As shown by the table, the precipitation was sometimes in neutral, sometimes in faintly acid solution.

† Gooch and Peters, this Journal, vol. vii, 461.

TABLE VII.

	Amount taken. Calculated as CeCl_3 .	Amount found. Calculated as CeCl_3 . Treatment of precipitate.	Error. Calculated as CeCl_3 .	Amount found. Calculated as CeCl_3 . Treatment of filtrate.	Error. Calculated as CeCl_3 .
(1)	[0.1091	0.1087	0.0004 —	0.1023	0.0068 —]
(2)	0.1091	0.1103	0.0012 +	---	---
(3)	0.1091	0.1087	0.0004 —	0.1087	0.0004 —
(4)	0.1364	0.1373	0.0009 +	0.1391	0.0027 +
(5)	0.1364	0.1367	0.0003 +	0.1367	0.0003 +
(6)	0.2182	0.2202	0.0020 +	0.2206	0.0024 +
(7)	0.1091	----	----	0.1087	0.0004 —
(8)	0.1519	0.1535	0.0016 +	0.1535	0.0016 +
(9)	0.1364	0.1367	0.0003 +	0.1367	0.0003 +
(10)	0.2182	0.2183	0.0001 +	0.2183	0.0000 +

ART. LIII.—*On the Estimation of Thallium as the Chromate*; by PHILIP E. BROWNING and GEORGE P. HUTCHINS.

[Contributions from the Kent Chemical Laboratory of Yale University—XCI.]

CROOKES has shown* that the chromate precipitated by the addition of potassium dichromate to an alkaline solution of a thalious salt has the constitution of a neutral salt and is very insoluble in water—100 parts of water at 100° C. dissolving about 0.2 parts and at 60° C. about 0.03 parts. He has also made use of this reaction† to effect a rough separation of thallium from cadmium.

The object of this paper is to describe some work directed toward a study of the application of this reaction to the gravimetric estimation of thallium and the best conditions under which to effect the precipitation. For the work a solution of thalious nitrate was made by dissolving 10 grms. in water making up to a liter. The standard was determined by taking measured and weighed portions from a burette, precipitating with a slight excess of potassium iodide, agitating to bring about a good separation of the thalious iodide, and allowing to stand until the supernatant liquid was clear. The iodide was then filtered off upon an asbestos felt contained in a perforated platinum crucible, the whole having been previously ignited and weighed, washed with a mixture of alcohol and water, dried over a low flame and weighed to a constant weight. The filtrate, which together with the washings seldom amounted to more than 50^{cm}³, was evaporated to dryness on a water bath, a few drops of water added and thus the small amount of thalious iodide which had been dissolved recovered. This small insoluble residue, which seldom amounted to one milligram in weight, was filtered off, washed and weighed as previously described. Baubigny‡ has shown this method to give very satisfactory results, and the uniformity of our determinations certainly confirms his statements.

For convenience in the calculations of results to be described later, a solution of potassium dichromate of definite strength was made. Portions of the thallium solution were drawn from a burette into test tubes of about 100^{cm}³ capacity and weighed as a check on the burette reading. The solution was heated to about 70° C. to 80° C. and a few drops of ammonia or potassium carbonate solution added to distinct alkalinity. A definite amount of the potassium dichromate in solution was delivered from a burette, care being taken to have an excess,

* Chem. News, viii, 255.

† Chem. News, vii, 145.

‡ Chem. News, lxiv, 239.

and the contents agitated to bring about a good separation of the precipitated chromate. After the precipitate had completely settled out and the solution had become cold the chromate was filtered upon asbestos, as described above, dried over a low flame and weighed to a constant weight. The filtrates from several determinations were evaporated to a small volume and in one or two cases a residue amounting to a few tenths of a milligram was obtained, but no appreciable quantity of dissolved chromate was thus recovered. It was found that when the precipitation was made in the cold the chromate did not flock well, but remained partly in a finely divided condition which would run through the felt and require repeated filtration. The addition of ammonium nitrate before precipitation prevented this largely, even in the cold, but the best results were obtained by warming the solution before precipitation and using potassium carbonate rather than ammonium hydroxide. The results follow in Table I.

TABLE I.

	TlNO ₃ taken. Calculated as Tl ₂ O. gram.	Tl ₂ CrO ₄ found. Calculated as Tl ₂ O. gram.	Error. Calculated as Tl ₂ O. gram.
(1)	0.0796	0.0791	0.0005—
(2)	0.0792	0.0788	0.0004—
(3)	0.0792	0.0786	0.0006—
(4)	0.1188	0.1177	0.0011—
(5)	0.1192	0.1186	0.0006—
(6)	0.1185	0.1178	0.0007—
(7)	0.1190	0.1185	0.0005—
(8)	0.1189	0.1183	0.0006—
(9)	0.1196	0.2000	0.0004+
(10)	0.1196	0.2005	0.0009+
(11)	0.1173	0.1173	0.0000
(12)	0.1171	0.1163	0.0008—

An attempt was made to estimate the thallium volumetrically by determining the amount of chromate in the filtrate from the thallous chromate, and by difference (the potassium dichromate originally added being known) the amount combined with the thallium in the precipitate. The method used to determine the standard of the dichromate solutions and also the chromate remaining in the filtrate was described by one of us in a previous paper from this laboratory.* According to this procedure the filtrate from the thallous chromate containing the excess of alkali chromate was acidified with sulphuric acid, a definite amount of a solution of arsenious oxide, previously standardized, was added and the whole was allowed

* This Journal, vol. i, 35, 1896.

to stand a few moments until the change from the yellow to the bluish green showed the complete reduction of the chromic acid. Potassium bicarbonate was added to distinct alkaline reaction and the arsenious oxide remaining was determined by titration with standard iodine solution. The amount of the arsenious oxide oxidized is of course the measure of the chromate in the solution. The amount of chromate in the original solution used being known, by subtracting the amount thus determined in the filtrate, the chromate in combination with the thallium may be readily found, and from it the thallium estimated. Filtrates from certain precipitates, of which the determinations are given in Table I, were treated in this way, and the results, indicated by corresponding numbers, follow in Table II.

TABLE II.

	TlNO ₃ taken. Calculated as Tl ₂ O. gram.	Tl ₂ CrO ₄ found. Calculated as Tl ₂ O. gram.	Error. Calculated as Tl ₂ O. gram.
(5)	0.1192	0.1198	0.0006 +
(8)	0.1189	0.1205	0.0016 +
(9)	0.1196	0.1180	0.0016 —
(10)	0.1196	0.1192	0.0004 —
(11)	0.1173	0.1182	0.0009 +
(12)	0.1171	0.1190	0.0019 +

The method cannot be very accurate on account of the high molecular weight of thallium oxide as compared with that of the chromic acid determined, but the results check fairly well with the gravimetric method.

July, 1899.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Existence of masses smaller than atoms.*—At the late meeting of the British Association at Dover, Prof. J. J. THOMSON read an important paper on this subject. He considers that electrification consists in the removal from the atom of a small corpuscle with which the negative charge is associated. The remaining large portion of the mass is positively charged. This view is supported by Prout's hypothesis that the mass of an atom is not invariable and by the evidence derived by Lockyer and others from spectroscopic observations.—*Nature*, Oct. 12, 1899.

J. T.

2. *Dispersion of the Cathode Rays by magnetic force.*—M. BIRKELAND has observed that when a narrow beam of cathode rays produced by an induction coil is deflected by a magnetic field, that certain rays are deflected more than others, and he has given to this effect the name of the magnetic spectrum. R. J. STRUTT of Trinity College, Cambridge, has examined this subject and by the use of a storage battery of 800 cells shows that the formation of the magnetic spectrum is due to a peculiarity of the induction coil. The cathode rays produced by a battery are homogeneous.—*Phil. Mag.*, Nov., 1899, pp. 478-480.

J. T.

3. *A new Radio-active Substance.*—M. A. DEBIERNE has isolated from pitchblende a substance which emits rays which are 100,000 times stronger than those given off by uranium. They render gases capable of discharging electricity, excite the phosphorescence of barium platino-cyanide and affect photographic plates.—*Comptes Rendus*, Oct. 16.

J. T.

4. *Radio-active effect of Barium Salts and Polonium.*—In the course of a paper on these subjects, F. GIESEL, the author, states that a surprising difference exists in regard to the penetrating power of the rays of radium and those of polonium. While the rays from radium penetrate fairly well a silver thaler, the rays from polonium, although more intense, are absorbed by thinner metallic plates. The shadow of the hand and of metallic objects thrown by the polonium rays on a fluorescent screen are stronger in contrast than when produced by the radium rays.—*Wied. Ann.*, No. 9, 1899, pp. 91-94.

J. T.

5. *Becquerel rays.*—These rays seem to be Röntgen rays of feeble intensity; in common with them they act upon photographic plates, dissipate electric charges, and produce luminescence. The intensity of the rays appears to be kept up without apparent consumption of energy. J. ELSTER and H. GEITEL have studied the behavior of these rays, which were produced from a piece of Joachimsthal pitchblende of 300 grams weight, 7^{cm} long, 5^{cm} broad and 1.5^{cm} thick. They appear to be uninfluenced by expo-

sure of the substance to cathode rays, to sunlight, or to heat. They were not deflected by a magnetic field. Their power of rendering air a better conductor of electricity was lessened in such a field.—*Wied. Ann.*, No. 9, 1899, pp. 83-90. J. T.

6. *Magnetizing constants of inorganic substances.*—STEFAN MEYER has made an extended study of the behavior of a large number of inorganic substances in the magnetic field and gives tabulated results. One of the most interesting facts he states is in regard to erbium. In the combination Er_2O_3 it is four times stronger than Fe_2O_3 . If in the pure metallic state it were as magnetic as it is in the state of oxide, one could reduce the weight of dynamos one-sixth and still obtain the same output as when iron is employed.—*Wied. Ann.*, No. 9, 1899, pp. 236-263. J. T.

7. *The Color Sensations in Terms of Luminosity*; by W. DE W. ABNEY. (Abstract.)—This paper deals with a determination of the color sensations based on the Young theory by means of measures of the luminosity of the three different color components in a mixed light which matches white. At the red end of the spectrum there is only one color extending to near C, and there is no mixture of other colors which will match it, however selected. At the violet end of the spectrum, from the extreme violet to near G, the same homogeneity of light exists, but it is apparently due to the stimulation of two sensations, a red and a blue sensation, the latter never being felt unmixed with any other. Having ascertained this, it remained to find that place in the spectrum where the blue sensation was to be found unmixed with any other sensation except white. By trial it was found that close to the blue lithium line this was the case, and that a mixture of this color and pure red sensation gave the violet of the spectrum when the latter was mixed with a certain quantity of white. The red and blue sensation being located, it remained to find the green sensation. The complementary color to the red in the spectrum gave a position in which the green and blue sensations were present in the right proportions to make white, and a point nearer the red gave a point in which the red and blue sensations were present in such proportions as found in white, but there was an excess of green sensation. By preliminary trials this point was found. The position in the spectrum of the yellow color complementary to the violet was also found. The color of bichromate of potash was matched by using a pure red and the last-named green. To make the match, white had to be added to the bichromate color. A certain small percentage of white was found to exist in the light transmitted through a bichromate solution with which the match was made, and this percentage and the added white being deducted from the green used, gave the luminosity of the pure green sensation existing in the spectrum color which matched the bichromate. Knowing the percentage composition in luminosity of the two sensations at this point, the luminosity of the three sensations in white was determined by matching the bichromate color with the yellow

(complementary to the violet) and the pure red color sensation. From this equation and from the sensation equation of the bichromate color already found, the composition of the yellow was determined. By matching white with a mixture of the yellow and the violet, the sensation equation to white was determined. The other colors of the spectrum were then used in forming white, and from their luminosity equations their percentage composition in sensations were calculated. The percentage curves are shown. The results so obtained were applied to various spectrum luminosity curves, and the sensation curves obtained. The areas of these curves were found, and the ordinates of the green and violet curves increased, so that both their areas were respectively equal to that of the red. This gave three new curves in which the sensations to form white were shown by equal ordinates.

A comparison of the points in the spectrum where the curves cut one another, and of those found by the red and green blind as matching white, show that the two sets are identical, as they should be. The curves of Koenig, drawn on the same supposition, are called attention to, and the difference between his and the new determination pointed out.

The red below the red lithium line, as already pointed out, excites but one (the red) sensation, whilst the green sensation is felt in greatest purity at λ 5140, and the blue at λ 4580, as at these points they are mixed only with the sensation of white, the white being of that whiteness which is seen outside the color fields.—*Proc. Roy. Soc.*, No. 419.

II. GEOLOGY AND MINERALOGY.

1. *Geology of the Aspen Mining District, Colorado*; by JOSIAH EDWARD SPURR; pp. 250, pl. liii, with atlas containing sheets xxx, 1898, U. S. Geological Survey, C. D. Walcott, Director. Monograph XXXI.—The detailed study of the Aspen District, made by Mr. Spurr, has resulted in an admirable solution of a difficult geological problem. The monograph, while it is primarily intended for those directly interested in mining, contains much that is of interest from a scientific point of view, and is a valuable addition to the literature of Mining Geology. The contents are briefly as follows:

Introduction, by Mr. S. F. Emmons, geologist in charge.

Chapter I. Description of rock formation.

“ II. General descriptive geology.

“ III. Detailed description of various mines and productive localities.

“ IV. Chemical geology.

“ V. Surface changes since ore deposition. Appendix.

The accompanying atlas with its carefully prepared sheets, and the many plates in the book itself illustrate clearly the structure

of the region. The following will serve as a brief outline of its geology: the intrusion of two distinct sheets of igneous rock into sedimentary beds of great thickness, representing deposits from the Archean through Cretaceous times; a general folding of the region and severe local disturbances in the vicinity immediately south of the city of Aspen, due, probably, to the pushing upward of a deeply buried igneous mass, resulted in a profound and complicated series of faults. The lines of faulting have since served as channels along which, widespread mineralization and chemical changes have been effected by mineralized waters. The ores, which are chiefly sulphides of lead and zinc carrying silver and associated with a gangue of barite, quartz, and dolomite, are commonly found at the crossing of two faults, one dipping steeply, the other nearly horizontal; and the theory is advanced that, ascending, mineral-bearing solutions in one channel meeting those of a different nature in another, caused a precipitation of ores at the contact. Since ore deposition, erosion has carried off the overlying strata to an amount estimated at 15,000 ft. and exposed the ore-bearing beds.

C. H. W.

2. *Iowa Geological Survey, Vol. IX.* Annual Report, 1898, with accompanying papers, by SAMUEL CALVIN and H. F. BAIN, pp. 11-572, plates i-xiii, 1899.—The great bulk of this volume is devoted to the elaboration of the details of geology by counties. Discussions of particular interest are those on the Pleistocene distribution and loess, as found in Udden's report on Muscatine County, and in Norton's report on Scott County, and in Bain's discussion of the Pleistocene in Carroll County. Also of interest are Udden's study of the range of species in the Devonian beds of Muscatine County; and Norton's facts on the contents of Devonian faunas in Scott County. The closing paper is by Mosnat on the Artesian wells of the Belle Plaine area. By means of the well records valuable details of underground structures are developed.

W.

3. *Geological Survey of Michigan*, vol. vi, 1893-1897. L. L. Hubbard, State Geologist.—This volume consists of three parts. The first by Dr. A. C. LANE, of 281 pp., is a geological report on Isle Royale. The structure of the island is thoroughly described and discussed with special reference to the copper mining industry. The petrography of the igneous rocks is also fully entered into. In the same thorough way Dr. HUBBARD has given an account of Keweenaw Point in Part II, containing 155 pages. These reports are fully illustrated with maps, sections, diagrams and photographs. In an appendix Dr. CHAS. PALACHE gives the results of a detailed crystallographic study of the calcite crystals from the copper mines of the Lake Superior region, so long celebrated for the beauty and perfection of their crystallization.

L. V. P.

4. *Report on Gypsum and Gypsum Cement Plasters*; by G. P. GRIMSLEY and E. H. S. BAILEY, under the direction and with the assistance of Erasmus Haworth. Vol. V of the University Geological Survey of Kansas; pp. 183, plates xxx. Topeka,

1899.—Some notes were given in the last number (p. 396) of recent work on the salt deposits of Kansas. The present interesting volume, published at about the same time, takes up the subject of gypsum and describes with all necessary fullness the occurrence of the important deposits in the State, with also the technological and chemical aspects of the subject.

5. *Ueber Strandbildungen des Litorinameeres auf der Insel Mantsinsaari*; by J. AILIO (Bull. Commission géologique de la Finlande, 1898, pp. 41).—Of recent years the Finnish geologists have been carefully studying the ancient elevated sea margins of northern Europe. The present paper is devoted to those of an island in the great Ladoga Lake. Many interesting features regarding these littoral formations are described and there is an excellent map in colors showing the retrogression of the waters.

L. V. P.

6. *Ueber eine Archäische sedimentformation im südwestlichen Finland*; von J. J. SEDERHOLM (Bull. Commission géologique de la Finlande, No. 6, pp. 254, 1899).—The object of the author in this paper is to show that a series of metamorphic, schistose and crystalline rocks were originally true normal sediments which had been laid down in water or were of eolian origin, interbedded with effusive lava flows, and that they had belonged to a Precambrian folded, mountain complex. The structure so far as possible, and especially the petrology, are very carefully worked out. It is a valuable contribution to the general knowledge of the subject of folded and metamorphosed rocks as well as of interest in its local application. In addition to cuts, plates and maps, it contains an excellent geological map of Finland.

L. V. P.

7. *A Study of the Peat Bogs of Finland and their Fossil Quaternary Flora*; by GUNNAR ANDERSSON. (Bulletin de la Commission géologique de la Finlande, No. 8, *Studier öfver Finlands Torfmossar och Fossile Kvartärflora*. Helsingfors, Dec., 1898.)—This study includes 21 text figures and 216 figures in four plates. It is based on a seven weeks examination of the Finland bogs, which, owing to their great extent, the writer considers to have been barely sufficient time. A number of sections are given, the uniform absence of shelly or marl layers being noticeable.

As in western Scandinavia and on the Baltic side of Sweden three periods of elevation and subsidence are noted, marked by *Yoldia*, *Ancylus*, and *Litorina* horizons. With the exception of isolated fish bones, remains of vertebrates were not found, presumably because of the action of humus acids and almost complete absence of lime in these Finnish bogs. The earlier bush flora following the glacial retreat is still being studied. No birch period, as sometimes proposed, was found to be present. An early well-marked pine flora appeared previous to the *Ancylus* horizon. An elm flora near the close of the pine flora is doubtful. Three plants not now found in northern Europe, *Ceratophyllum sub-*

mersum, *Platyedema violacea*, and *Trapa natans*, together with the southerly retreat of other plants, indicate a distinctly warmer climate for the post-*Litorina* oak period following the pine flora. The decline of the oak period is supposed to have been coeval with early man, the present being marked by fir forests in the south, and pine in the north.

G. R. W.

8. *La Géologie expérimentale*; par STANILAS MEUNIER. 8°, pp. 311. Paris, 1899 (F. Alcan).—In this work the author has discussed in a popular manner a number of common geological phenomena as well as some of those more abstruse, and gives the details of rather simple experiments by which these may be imitated and in many cases explained. The work is illustrated by cuts of apparatus. The teacher of geology will find it to contain many suggestive hints.

L. V. P.

9. *Brief notices of some recently described minerals*.—A paper by the late Prof. Arzruni and K. Thaddéeff, completed and edited by A. Dannenberg (*Zeitschr. f. Kryst.*, xxxi, 229) contains descriptions of the following three new species from Chili.

ARZRUNITE occurs in drusy crystalline crusts and rarely in distinct small prismatic crystals. These are hexagonal in aspect but are shown optically to belong to the orthorhombic system; the prismatic angle varies but little from 60° . The color is blue or bluish green with strong pleochroism. Two analyses by Thaddéeff, both on very small quantities, gave the following results:

SO ₃	Cl	PbO	CuO	SiO ₂	Fe ₂ O ₃	CaO	ZnO	H ₂ O
1. 8.07	14.39	31.41	21.39	13.60	0.70	1.70	undet.	undet.
2. 13.06	9.46	33.38	14.54	8.88	1.81	1.87	4.08	11.01=98.09

These analyses vary widely, but by assuming the presence of various impurities, namely, quartz (SiO₂), limonite (2Fe₂O₃ . 3H₂O), gypsum (CaSO₄ + 2H₂O) and goslarite (ZnSO₄ + 7H₂O), a ratio is obtained for the pure mineral corresponding to a double salt of basic lead sulphate and basic copper chloride. The final formula obtained is PbO.PbSO₄ + 3(CuCl₂ . H₂O) + Cu(OH)₂. The exact locality is in the mine Buena Esperanza, Challacollo, Tarapaca, Chili.

STELZNERITE occurs in loose crystalline masses and, implanted upon them, in fine green transparent prismatic crystals. These resemble brochantite closely, to which species the new mineral is allied chemically. The crystals belong to the orthorhombic system, the prismatic angle being $53^\circ 28'$. The specific gravity is 3.884. An analysis gave Thaddéeff:

SO ₃	CuO	H ₂ O	Fe ₂ O ₃	CaO	insol.
22.40	67.08	10.22	0.34	0.06	0.44 100.54

For this the formula calculated is CuSO₄ . 2Cu(OH)₂. The locality is Remolinos, Vallinar, Chili.

RAFAËLITE forms a crystalline incrustation on galena, quartz and celestite. The crystal needles are transparent and of a violet-red color and metallic-adamantine luster. They belong to the monoclinic system and show considerable complexity of form,

the prismatic zone being highly developed. A qualitative analysis showed the mineral to be a lead oxychloride, but the material was too scanty to allow of an analysis. Locality, the San Rafael mine, Sierra Gorda, Chili.*

The same authors also give a new examination of utabite in distinct crystals; the formula deduced is $\text{Fe}_2\text{O}_3 \cdot \text{SO}_3 \cdot 2\text{H}_2\text{O}$. They further describe a basic bismuth carbonate from Schneeberg which seems to be new, having the composition, $5\text{Bi}_2\text{O}_3 \cdot \text{H}_2\text{O} \cdot \text{CO}_2$.

LORANSKITE is a new tantalate first investigated by M. Melnikow and named by him after A. Loranski. It occurs at Imbilax near Pikäranta, Finland, in massive form in quartz veins. It is optically isotropic with conchoidal fracture; hardness about 5 and specific gravity nearly 4.6; color black and streak greenish gray. An analysis by P. Nikolajew gave:

	Ta ₂ O ₅	ZrO ₂	Y ₂ O ₃	Fe ₂ O ₃	CeO	CaO	Ign.	
G.=4.162	47.0	20.0	10.0	4.0	3.0	3.3	8.15	=95.45

A small amount of sulphur and traces of titanium and manganese were not determined.—*Zeitschr. f. Kryst.*, xxxi, 505.

STOKESITE. This new mineral, named in honor of the distinguished physicist, Sir George G. Stokes, is described by A. Hutchinson from a single crystal in the Cambridge Mineralogical Museum. The crystal is 10^{mm} in length and belongs to the orthorhombic system; it shows the forms $b(010)$ and $v(121)$. Cleavage is perfect parallel to b and also good parallel to a prism taken as 110. The axial ratio deduced is $a:b:c = 0.3479:1:0.8117$ (the author gives no angles). The physical characters are as follows: fracture conchoidal; hardness about 6 to 6.5; specific gravity 3.185; luster vitreous, but pearly on b ; colorless; optically positive with the axial plane parallel to b and the bisectrix normal to 001.

A partial chemical examination has led to the conclusion that it is a hydrated silicate of sodium and calcium with about 6 p. c. of tin dioxide supposed to replace part of the silica.—*Phil. Mag.*, November, 1899, p. 480.

VON DIESTITE. M. Cumenge has recently described (*Bull. Soc. Min.*, xxii, 25, 1896) a telluride of silver and bismuth from Colorado, discovered by the mining director Von Diest. It occurs in veins with copper minerals and auriferous pyrite in the Hamilton and Little Gerald mines on the slopes of the Sierra Blanca. An analysis by Knight has given the following results:

Te	Pi	Ag	Au	Pb	S	insol.
34.60	16.31	40.25	4.30	2.25	0.54	0.54 = 98.79

10. *A Preliminary Report on a Part of the Clays of Georgia*; by GEORGE E. LADD, Assistant Geologist. Bulletin No. 6-A, Geological Survey of Georgia. W. S. Yeates, State Geologist. Atlanta, Georgia, 1898.—The latest addition to the valuable series

* In the October number of the *Mineralogical Magazine*, received after the above was in type, it is shown by G. F. Herbert Smith that rafaélite is identical with paralaurionite (*ibid.*, April 1899).

of bulletins published by the Georgia Survey is this pamphlet on the clays. It is a subject of great practical interest, and the information brought together here will doubtless prove interesting to all concerned. The opening pages give an account of the properties of clays, their behavior with respect to water, heat, etc., and also methods of testing them. Following this is an account of some of the special localities at which valuable clays occur, particularly in the southern part of the state, with the results of chemical analyses and physical tests.

11. *A proposed International Journal of Petrology.* (Communicated.)—The Committee appointed by the Seventh International Congress of Geologists to consider plans for the establishment of an International Journal of Petrology has chosen Professor F. Becke of Vienna, well known as the editor of Tschermak's *Mittheilungen*, President of the Committee, and has taken the first steps toward the organization of such a journal. It has been proposed that articles appearing in it shall be printed in French, German or English at the option of the author.

While primarily intended for the publication of reviews and abstracts of all petrographical papers wherever published, it is suggested that it may include also articles which shall appear in it for the first time. The carrying out of this must depend upon the financial support the journal receives.

The journal is to be managed by a committee appointed by the International Congress of Geologists, the committee to select an editor who shall have two assistants; the editor and assistants to receive salaries for their services.

The desirability of having one source, thoroughly up to date, to which to turn for information concerning all matters published on petrology is self-evident to all attempting to keep abreast with the rapid advance of this science. One has only to observe what a great impulse to the science of mineralogy has been given by the establishment of Groth's *Zeitschrift für Krystallographie*, to be convinced of the usefulness and convenience of such a journal.

The necessity of forecasting as correctly as possible the financial support obtainable for such a journal has suggested to the American members of the committee the plan of calling attention to the enterprise and of inviting all interested in its success to communicate to either of them such suggestions or information as may aid in estimating the amount of annual subscriptions or contributions that may be obtained from this country.

It is expected that the chief support will come from individual subscriptions and from university and public libraries, but it may be possible to obtain assistance, in the first years of the undertaking at least, from other sources.

J. P. IDDINGS,
L. V. PIERSON,

Members of the Committee for America.

III. BOTANY AND ZOOLOGY.

1. *A Text-book of Plant Diseases, caused by Cryptogamic Parasites*; by GEORGE MARSEE, F.L.S., Principal Assistant (Cryptogams), Royal Herbarium, Kew; pp. xii+458, with 92 figures in text. London, 1899 (Duckworth & Co.); New York (The Macmillan Co.).—This account of plant-diseases is designed chiefly for farmers, gardeners and foresters who have little knowledge of cryptogamic botany and little time available for study. It is therefore written in a semi-popular style, but contains numerous references to literature for those who may desire to investigate particular diseases more thoroughly. In the short introductory portion, the general characteristics of Fungi and of the less important parasites are briefly described, and attention is directed to the most satisfactory fungicides and to the methods in which they should be applied. The greater part of the book is taken up with the detailed descriptions of over two hundred diseases. In each case the appearance of the affected portion of the host-plant is described, together with the gross and minute structure of the parasite, and particular directions are given for preventing the spread of the disease. The more important diseases are fully illustrated by figures. At the close of the volumes the various Fungi treated are arranged in order and briefly re-described in scientific terms. The frequent mention made of the work done in the United States by botanists connected with the Department of Agriculture is worthy of note.

A. W. E.

2. *Observations on the Colors of Flowers*; by E. WILLIAMS HERVEY; pp. 105, 4 illustrations in text. New Bedford, 1899 (E. Anthony & Sons).—The subject-matter treated in this little pamphlet is divided into three parts. In the first, entitled "sequence of color," the author brings forward numerous observations to show that there are many exceptions to the sequence described by Grant Allen, who claimed that the primitive color of flowers was yellow, becoming white, red, purple, and, ultimately, violet or blue, as the flowers advanced in complexity. In the second part, entitled "honey-guides," doubt is thrown upon the common interpretation of these interesting flower-markings, and it is claimed that they result simply from the local irritation caused by insect-visitors in their search for nectar and that the latter are not guided by them at all. In the third part the theory elaborated by Professor Müller that flower-colors are produced through the selective agency of insects, is criticised.

A. W. E.

3. *Text-book of the Embryology of Invertebrates, from the German of E. KORSCHOLT and K. HEIDER*; 3 vols. 8°. New York (The Macmillan Co.). Vol. I, *Porifera, Cnidaria, Ctenophora, Vermes, Enteropneusta, Echinodermata*, translated by EDWARD L. MARK and W. McM. WOODWORTH, pp. 500, 1895. Vols. II, *Phoronidea, Bryozoa, Ectoprocta, Brachiopoda, Entoprocta, Crustacea, Pulcestraca*, and III, *Arachnida, Pentasto-*

midæ, Pantopoda, Tardigrada, Onychophora, Myriopoda, Insecta, translated by MATILDA BERNARD and revised by MARTIN F. WOODWARD; pp. 491 and 453, 1899.—Professors Korschelt and Heider's great work is one of the most valuable, if not the most valuable, of all the biological text-books which have appeared in the present decade. All English-speaking students of biology are deeply indebted to the several translators for attempting their part of the work, as well as for the painstaking labor they have bestowed upon it. Nothing can give a better idea of the recent progress of invertebrate embryology than a comparison of this work with the thin first volume of Balfour's *Comparative Embryology* which appeared in 1880. The vast mass of literature which appeared during the ten years from the time of Balfour's work was carefully reviewed by Korschelt and Heider and condensed into their work, which gives full citations for each investigator's contribution to the subject in hand, and thus becomes a complete guide to the literature of the period. Some idea of the extent of this literature is given by the indices to authors, the index in each of the three volumes of the translation containing 250, or more, names.

Many additions have been made to the original text both by the authors and the translators, so that the work is in great measure brought down to the time of publication. This is especially true of the bibliographical lists which include the recent literature very fully. The translation throughout, like that of Prof. Mark's admirable translation of Hertwig's classical *Text-book of the Embryology of Man and Mammals*, cannot be too highly praised. It is clear and accurate without the use of German words or German idioms. In rendering *Anlage* into English Prof. Mark introduced the word *fundament*, which was used throughout the first volume. In the subsequent volumes Dr. Woodward has substituted the much abused word *rudiment*, returning to the primary meaning of the word which Darwin and most recent biologists have unfortunately misapplied to vestigial structures. This appears to the writer a reasonable substitute for *fundament*, *primordium*, *proton*, etc., as well as for the un-English *Anlage*, and a possible solution of a much vexed question, but it is scarcely to be expected that it will be generally accepted. The mechanical execution of the work is excellent, but the change in the size of the page after the first volume appears unfortunate.

The translators of the first volume were unable to continue the work and there was a tantalizing delay in the appearance of the second volume, which, however, was very quickly followed by the third, and in the preface to this Dr. Woodward states that he hopes to publish the fourth and concluding volume, containing the *Mollusca, Ascidia, and Cephalopoda*, at the end of the year.

S. I. S.

4. *A Text-book of Vertebrate Zoology*; by J. S. KINGSLEY. 8°, pp. 446. New York, 1899 (Henry Holt and Co.).—This is an advanced text-book intended to follow and supplement laboratory

work and lectures. It is divided into two nearly equal parts, an outline of the morphology of vertebrates based on embryology, and an outline of a classification. The first part covers essentially the same ground as Wiedersheim's *Elements of the Comparative Anatomy of Vertebrates* but with a very different arrangement, the morphology of the organs being taken up under entodermal, ectodermal, mesothelial, and mesenchymatous structures. This is followed by brief accounts of the segmentation of the head, the early history of the ovum, and the origin of the vertebrates. In the second part, fossil forms are included, the classification is carried as far as orders, and the birds are ranked as a single class of four orders. A large number of the 378 well chosen illustrations are original. The large proportion of diagrammatic figures is a valuable feature of the work, which includes an important field not well covered by any other text-book.

S. I. S.

5. *Insects, their Structure and Life*; by GEORGE H. CARPENTER. 8°, pp. 416. London, 1899 (J. M. Dent and Co.).—This little treatise, very modestly called by the author "A Primer of Entomology," is a condensed sketch of the whole subject of which it treats, written in simple, untechnical language, and very fully illustrated with well selected figures. The subjects of the six chapters are: structure, life-history, classification, orders of insects, insects and their surroundings, and the pedigree of insects. While of necessity a compilation, the vast mass of material used is so thoroughly digested and up to date that the result is very satisfactory. The references to the literature at the end of the volume are very full for a work of this kind and make a good guide to the more important recent work in entomology. There is a good index and the paper and printing are excellent.

S. I. S.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *November Meteors of 1899*.—It appears to be almost certain that the earth at this crossing of the orbit of the Leonids has passed through a portion of the stream of comparatively small density. Press reports extending from India, where WEISS of Vienna had stationed himself, to California agree in describing the shower as but a slight one and the most favored localities seem to have had a display of Leonids inferior to that of an average August shower.

Two obvious reasons suggest themselves immediately for this meagerness. First, an actual large variation of density of the stream, even near the points of main condensation, one of which, it will be remembered, was the source of the display in 1833 and is not due to arrive at the earth's orbit until May, 1900. Secondly, the possibility of planetary perturbations since 1766, when the earth last encountered the part of the stream due this November, having materially diverted this part from a close approach to the earth's orbit. This is quite within reasonable probability, as, according to Messrs. Stoney and Downing, the perturbations of

the orbit of the Leonids seen in 1866 have brought its intersection with the ecliptic over 1,000,000 miles inside the earth's path; and it is doubtful whether the stream possesses as great a thickness as that.

At New Haven the nights of Nov. 13-14 and 16-17 were perfectly clear, that of Nov. 15-16 mostly so after 1 A. M., Nov. 14-15 completely overcast throughout. Watch was kept at the Yale Observatory during this period and continuous photographs secured. But in all only 7 meteors of any brightness, 6 of them Leonids, were recorded as falling in the camera fields and none of them were bright enough apparently to impress themselves on the plates.

W. L. E.

2. *National Academy of Sciences*.—The following is a list of the papers accepted for reading at the meeting of the National Academy held in New York on Nov. 14, 15.

CGDEN N. ROOD: Variations in normal color vision.

J. MCKEEN CATTELL: The time of perception as a measure of difference in intensity. Relations of time and space in vision.

THEODORE WILLIAM RICHARDS: The electro-chemical equivalents of copper and silver.

EDWARD C. PICKERING: Recent results of the Henry Draper Memorial.

R. S. WOODWARD: The static properties of the atmosphere. A direct proof of the effect on the Eulerian Cycle of an inequality in the equatorial moments of inertia of the earth.

GEORGE F. BARKER: The hydrogen vacua of Dewar.

CHARLES S. PEIRCE: The definition of continuity. Topical geometry, in general. The map-coloring problem.

E. W. MORLEY: Memoir of W. A. Rogers as a physicist.

HENRY P. BOWDITCH: Report of the Delegates to the Wiesbaden Congress to consider the establishment of an International Scientific Association.

3. *The Races of Europe*; by WILLIAM Z. RIPLEY, Ph.D.; pp. 1-608 with a supplementary volume (159 pages) on the bibliography of the subject. New York, 1899 (Appleton & Co.).—These volumes are by a recognized leader in social science and constitute a sociological study, but will be equally welcomed by historians, anthropologists and geographers. Historians are recognizing the need of data regarding the physical make-up and traits of the peoples who have been and are now the actors on the historical stage. Anthropologists and geographers have long known that the fauna, flora, climate and geographical features have had a decided influence on the human species, but just how much and where these influences have been felt is a present point of discussion. It appears from the supplementary bibliography that there is a vast amount of raw material regarding races and physical environment. Much of it, however, is of uncertain quality and not easily accessible. Prof. Ripley has put us under obligations by collecting, weighing, interpreting and arranging this abundant original material and presenting it in an attractive manner. The amount of labor accomplished by the author and the saving in time for the reader will be appreciated by those who have done similar work. The European races with their colonial outgrowths form such complex groups, and their relationships and

geographical environment are so various, that all the inter-related social influences are involved when an effort is made to account for their condition. The author has wisely taken two of these forces, viz: race and physical environment—the only forces in social affairs which seem to rest on definable scientific foundations. The value and limitations of these two influences are traced throughout the book and the discussion of environment vs. race (Chapter xix) is an attempt to explain the particular effect of each.

In the arrangement of the book the anthropological data—language, head form, color of hair and eyes, and stature—are first discussed, and groupings of the European people are made in accordance with these principles. Each race and type is then described in detail in a thorough, interesting manner. Students will be especially grateful for the clear presentation of the facts in regard to the little-known races of southeastern Europe and Asia Minor. The chapter on the Jews brings out their striking social solidarity and their equally striking response to environment. This chapter well deserves the attention it is receiving from scholars. Acclimatization (Chapter xxi) is of timely interest in that it treats of the possibility of adaptation of white races to tropical climates.

The illustrations are an important feature of the book. The portrait pages are serviceable in that they enable the reader to study the physical features of the race types almost at first hand. The numerous maps deserve commendation because they are made solely to illustrate the point in hand and not as an exhibition of artistic skill.

From the standpoint of the student—especially the English-speaking student—no more important contribution has been made to the broad field of social science than Ripley's *Races of Europe*.

H. E. G.

4. *Ostwald's Klassiker der Exakten Wissenschaften*. Leipzig, 1899 (W. Engelmann).—Recent additions to this valuable series of scientific classics are the following:

Nr. 104. Untersuchungen über die Chemischen Affinitäten. Abhandlungen aus den Jahren 1864, 1867, 1879. Von C. M. Guldberg und P. Waage. (182 pp.)

Nr. 105. Ueber das Geschlecht der Pflanzen. (De sexu plantarum epistola.) Von R. J. Camerarius. (1694.) (78 pp.)

Nr. 106. Abhandlung über Dynamik. Von D'Alembert, de l'Académie Royale des Sciences. (1743.) (210 pp.)

Nr. 107. Wahrscheinlichkeitsrechnung (Ars conjectandi). Von Jakob Bernoulli. (1713.) Erster und zweiter Theil. (162 pp.)

Nr. 108. Wahrscheinlichkeitsrechnung (Ars conjectandi). Von Jakob Bernoulli. (1713.) Dritter und vierter Theil mit dem Anhang: Brief an einen Freund über das Ballspiel (Jeu de Paume). (172 pp.)

OBITUARY.

SIR J. WILLIAM DAWSON. A telegram from Montreal, dated November 19, announces the death of the distinguished Canadian Geologist, Sir J. William Dawson, Principal of McGill University. A notice of Dr. Dawson is deferred until a later number.

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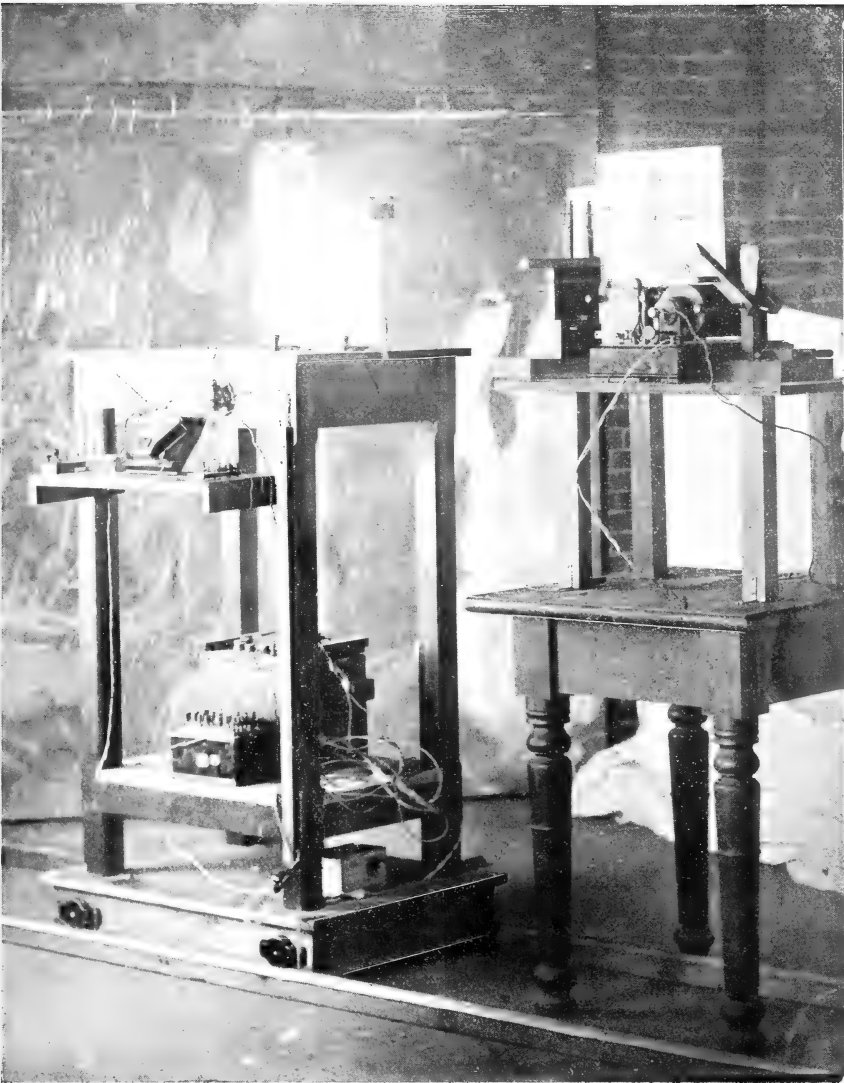
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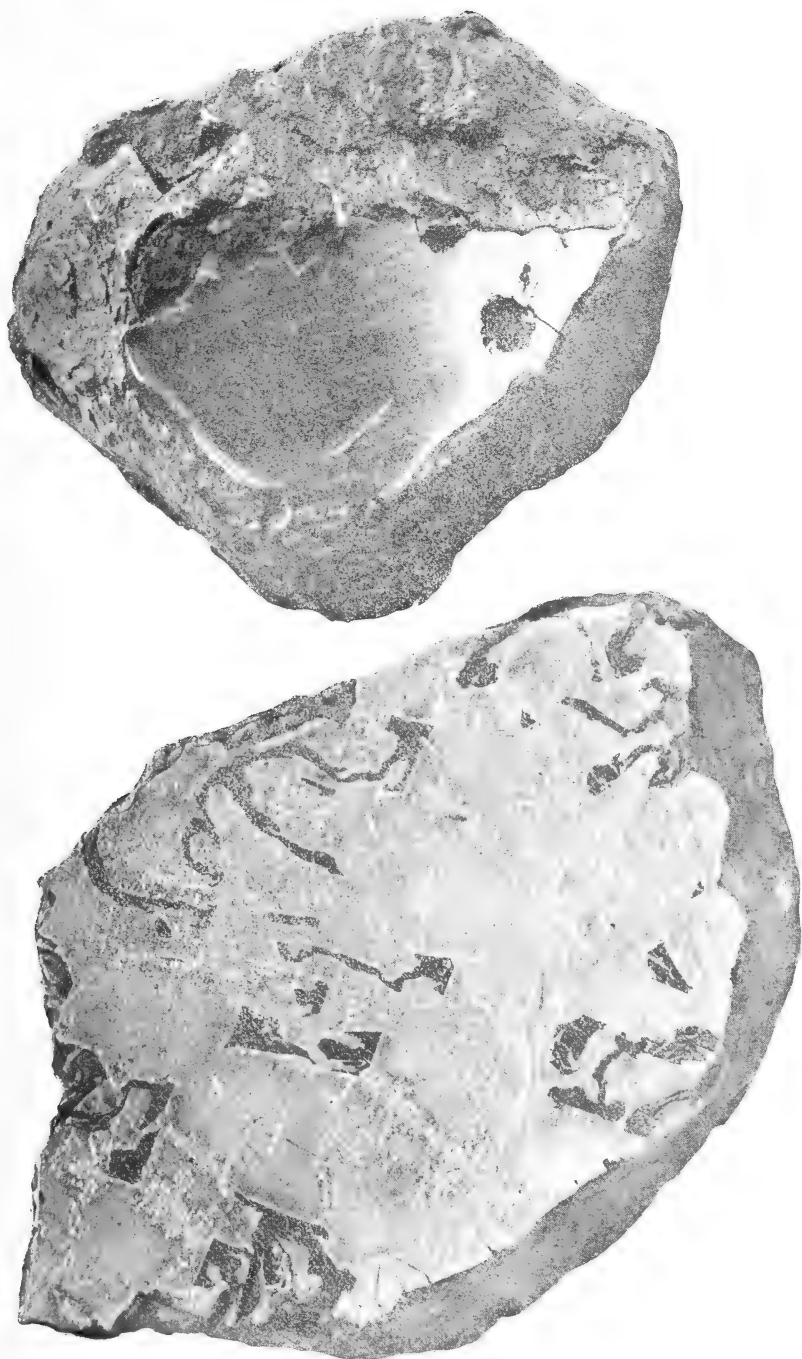
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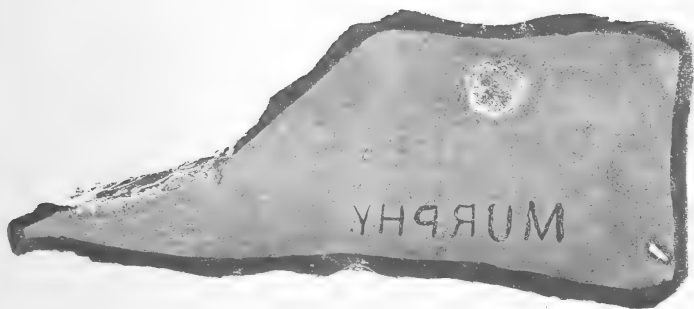
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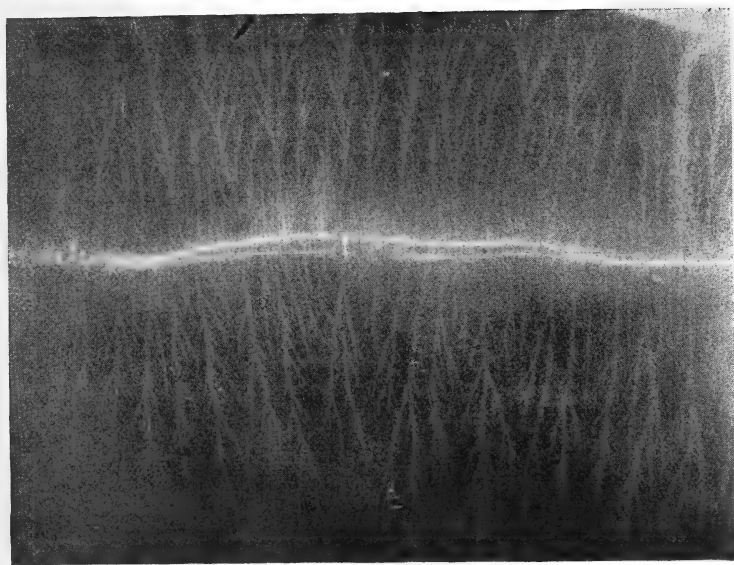
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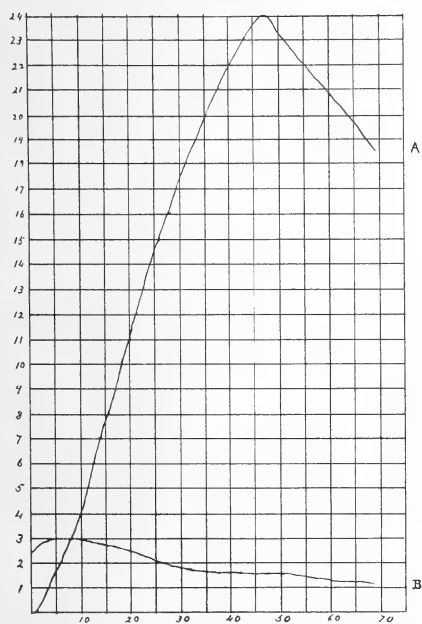
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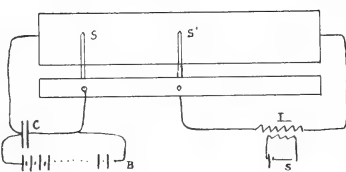
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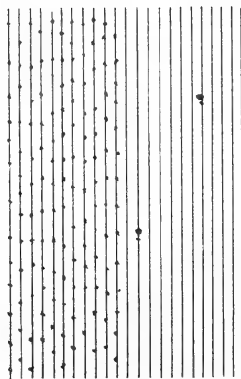
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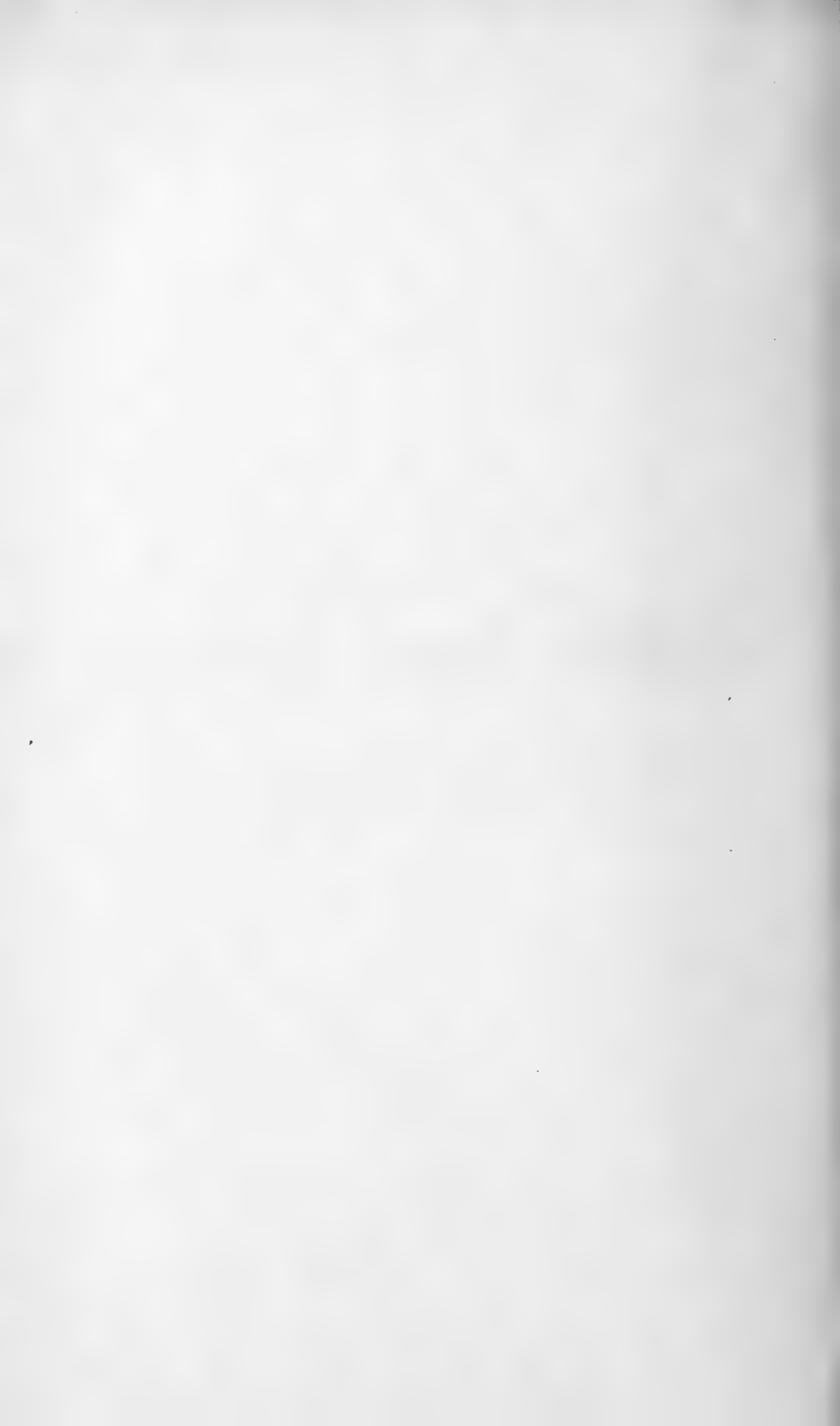


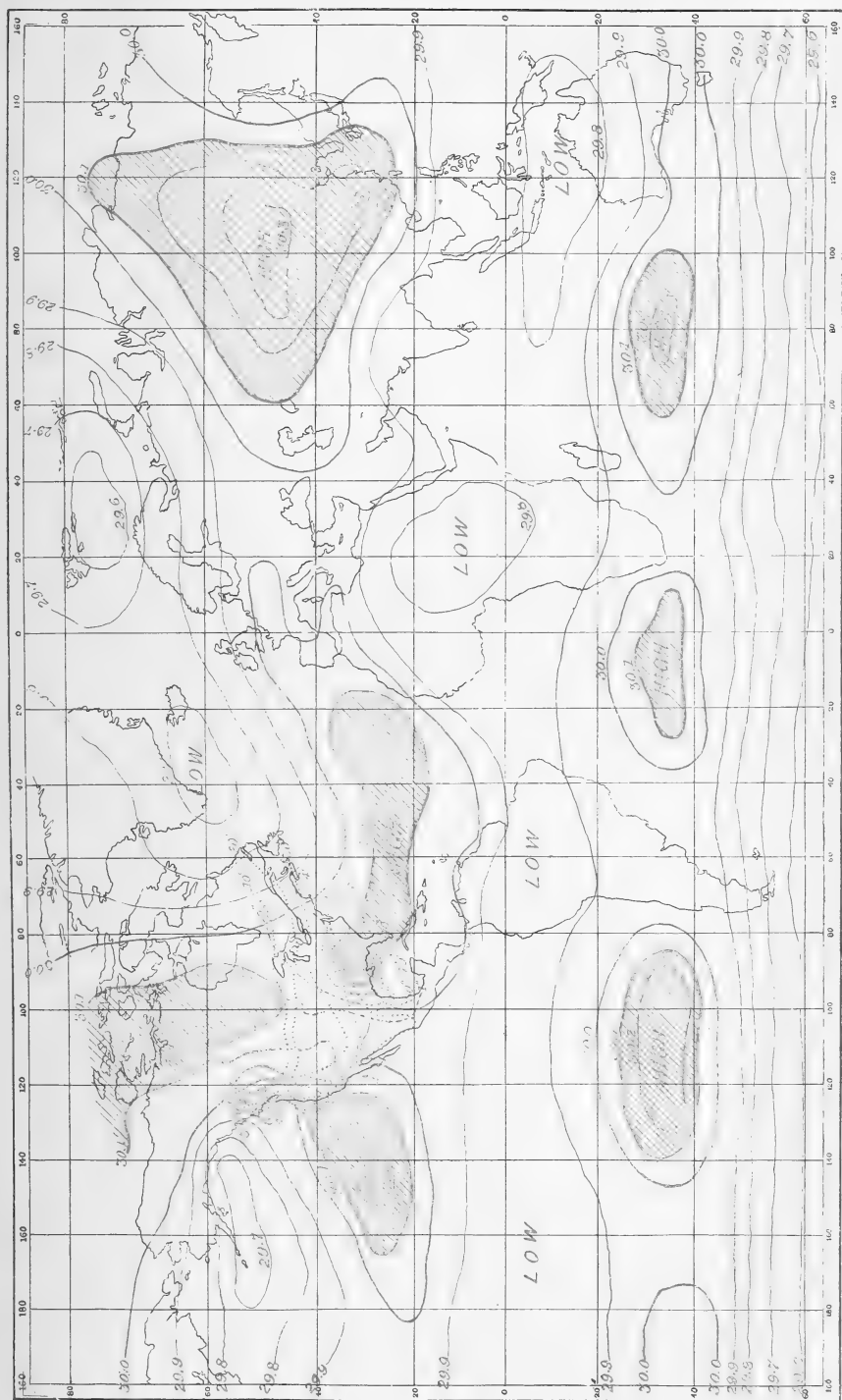
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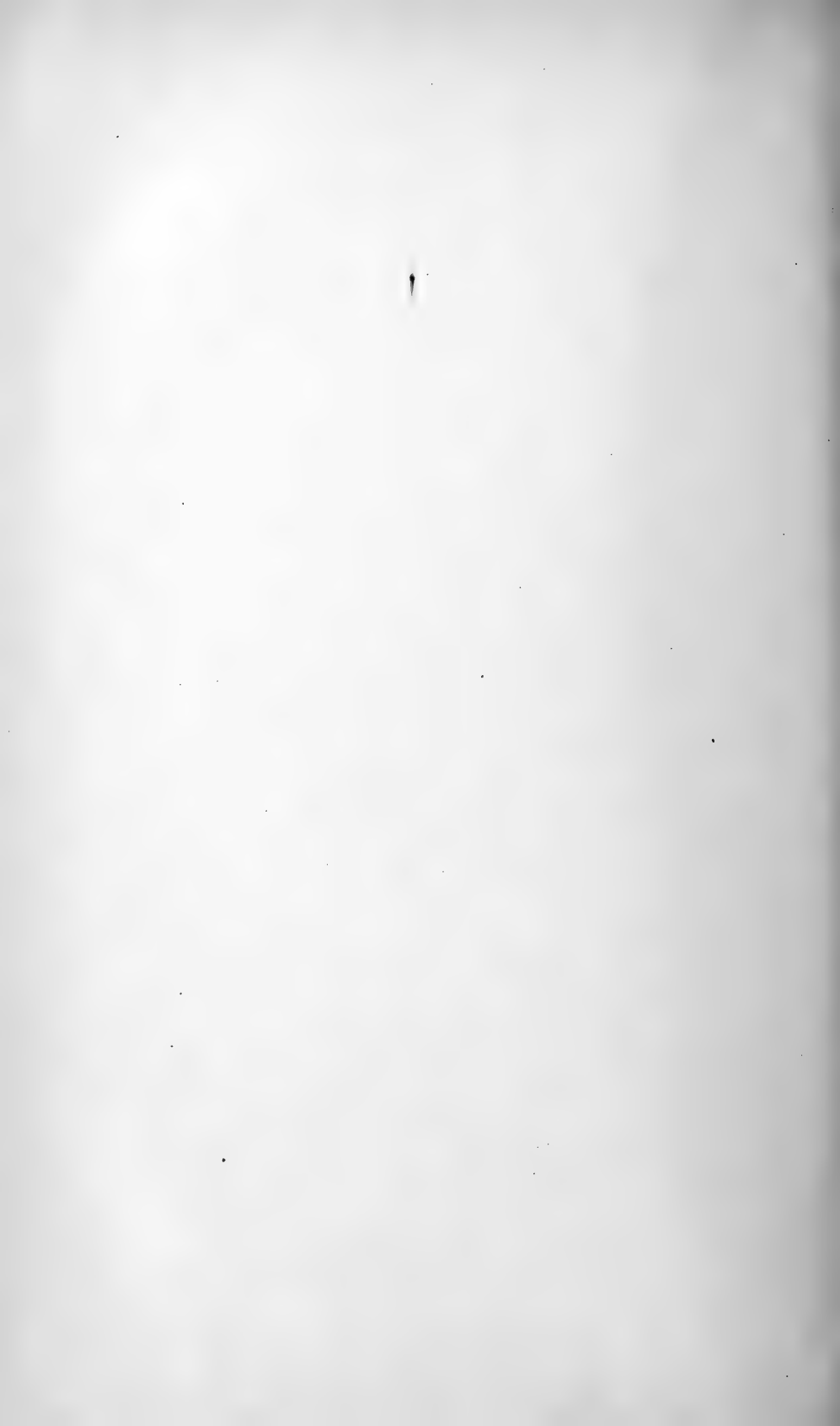
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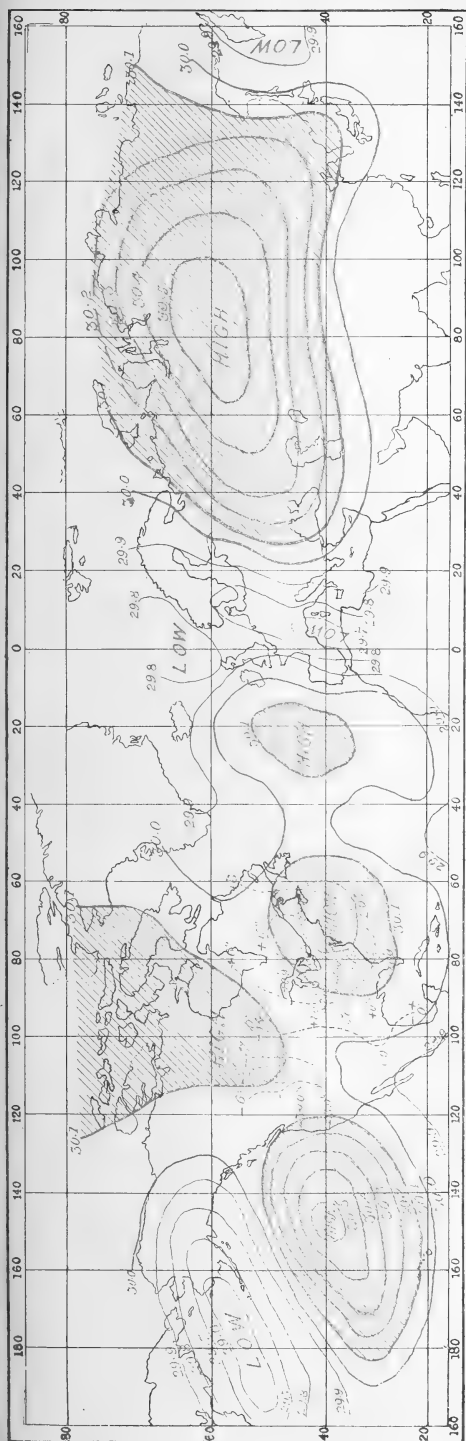




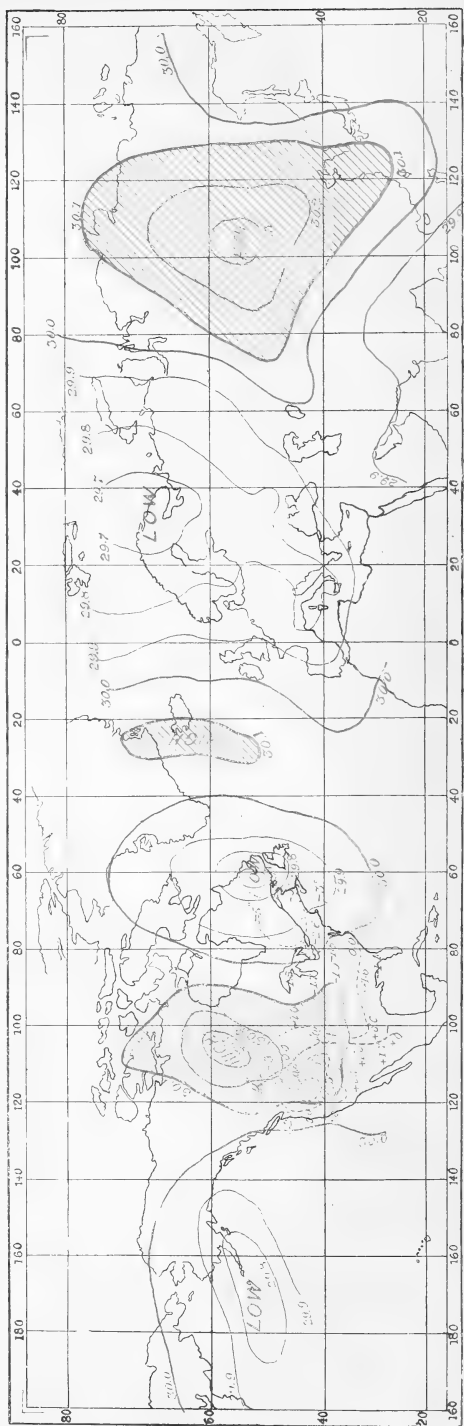


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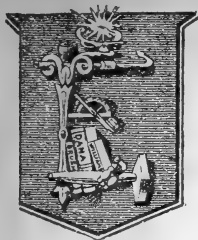


WEATHER CONDITIONS, MARCH, 1898. WARM TYPE.



WEATHER CONDITIONS, MARCH, 1883. COLD TYPE.

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Ten days' work has been done, under the careful supervision of our Mr. Fraser, at the new Fluorite locality in New Hampshire, noticed in our Fall Bulletin. A fine, large lot of specimens of remarkably rich color were secured. Well-formed crystals are rare and in all cases the faces are curiously etched. While none of the crystals are sharp, their wonderfully deep and rich color makes them the most attractive American Fluorites we have ever placed on sale. The best crystals are priced 50c. to \$2.00; crude crystals of splendid color, 10c. to 50c. Cleavage octahedrons, of rich colors, exceedingly beautiful, and worthy of a place in the best collections,

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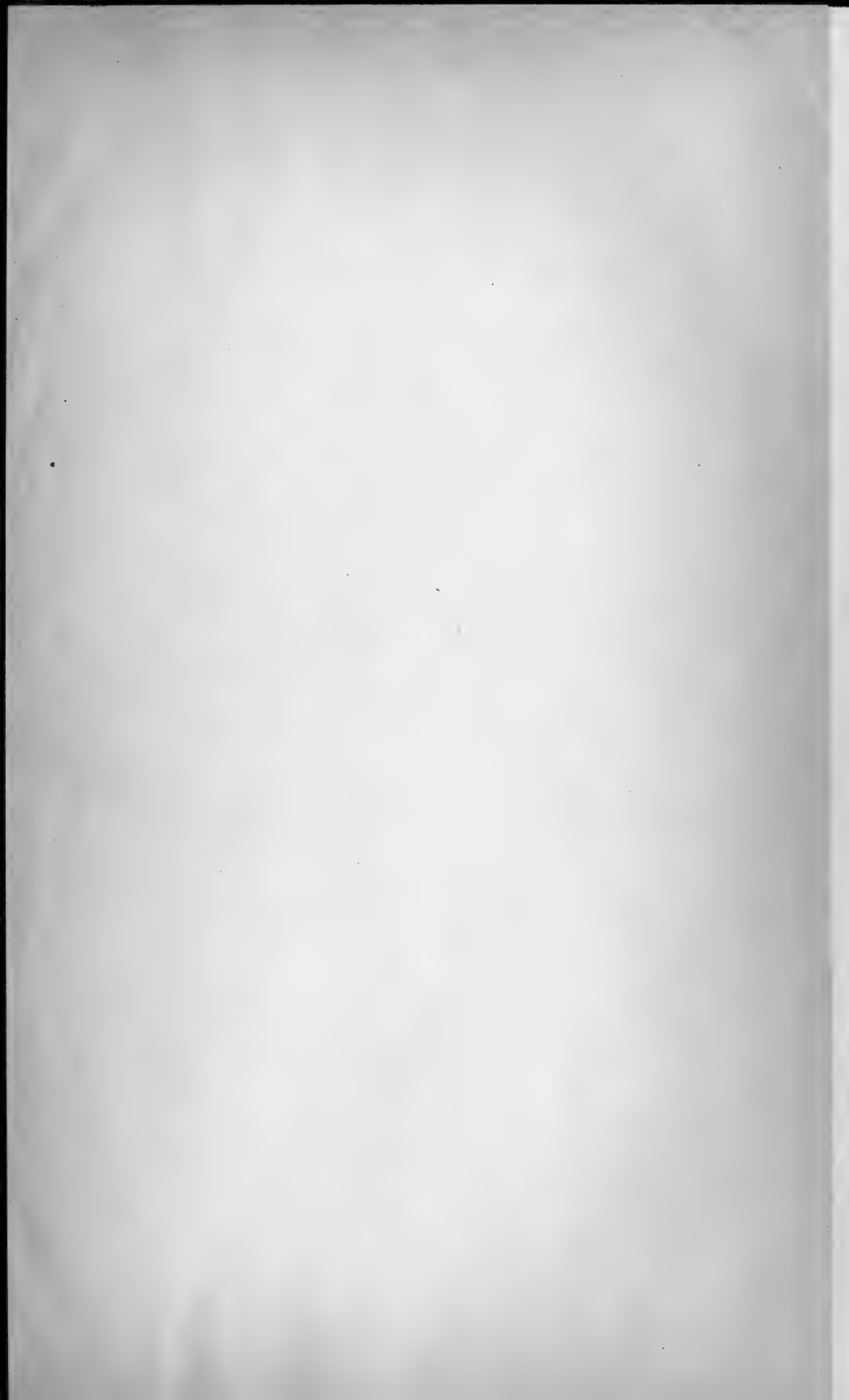
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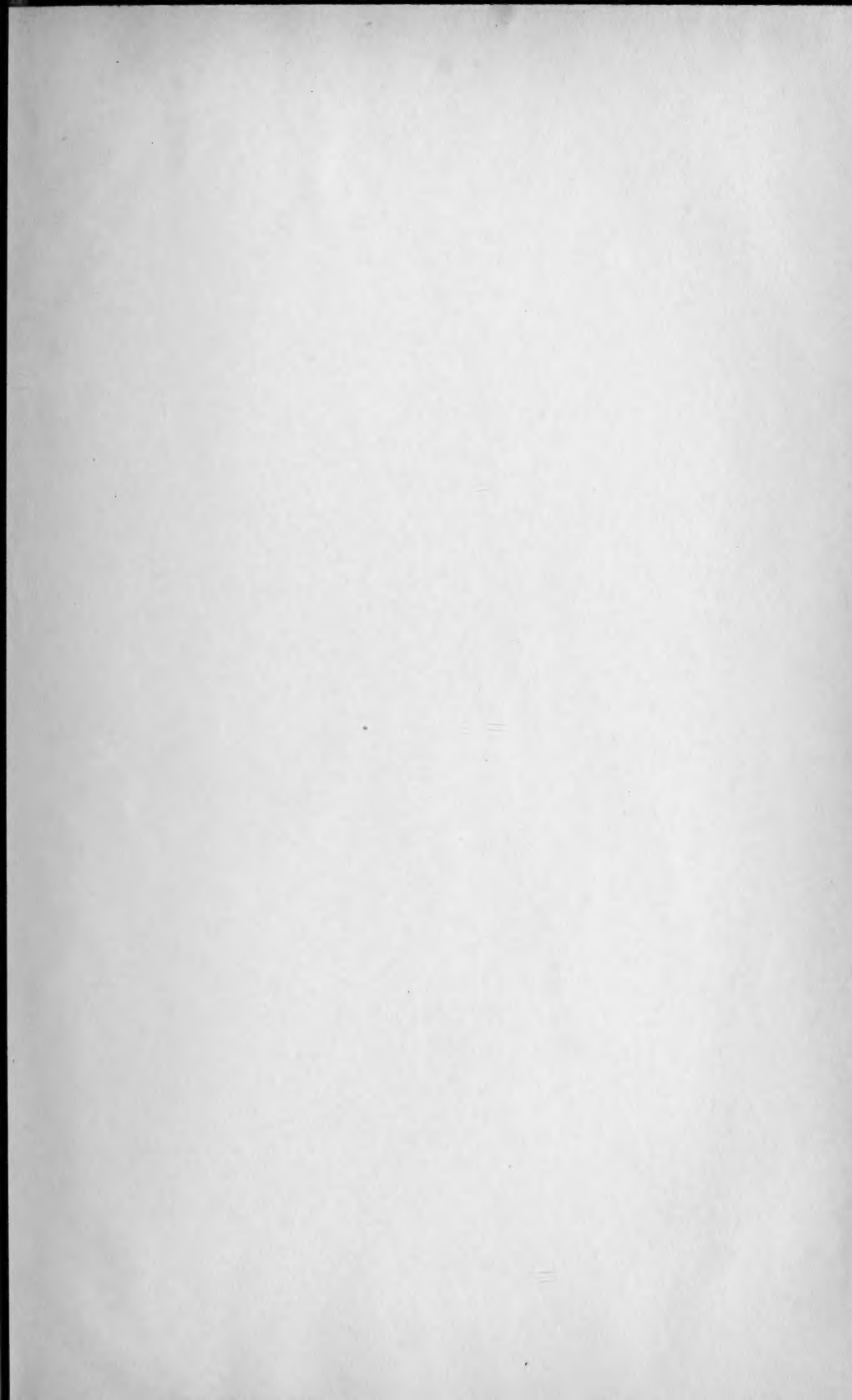
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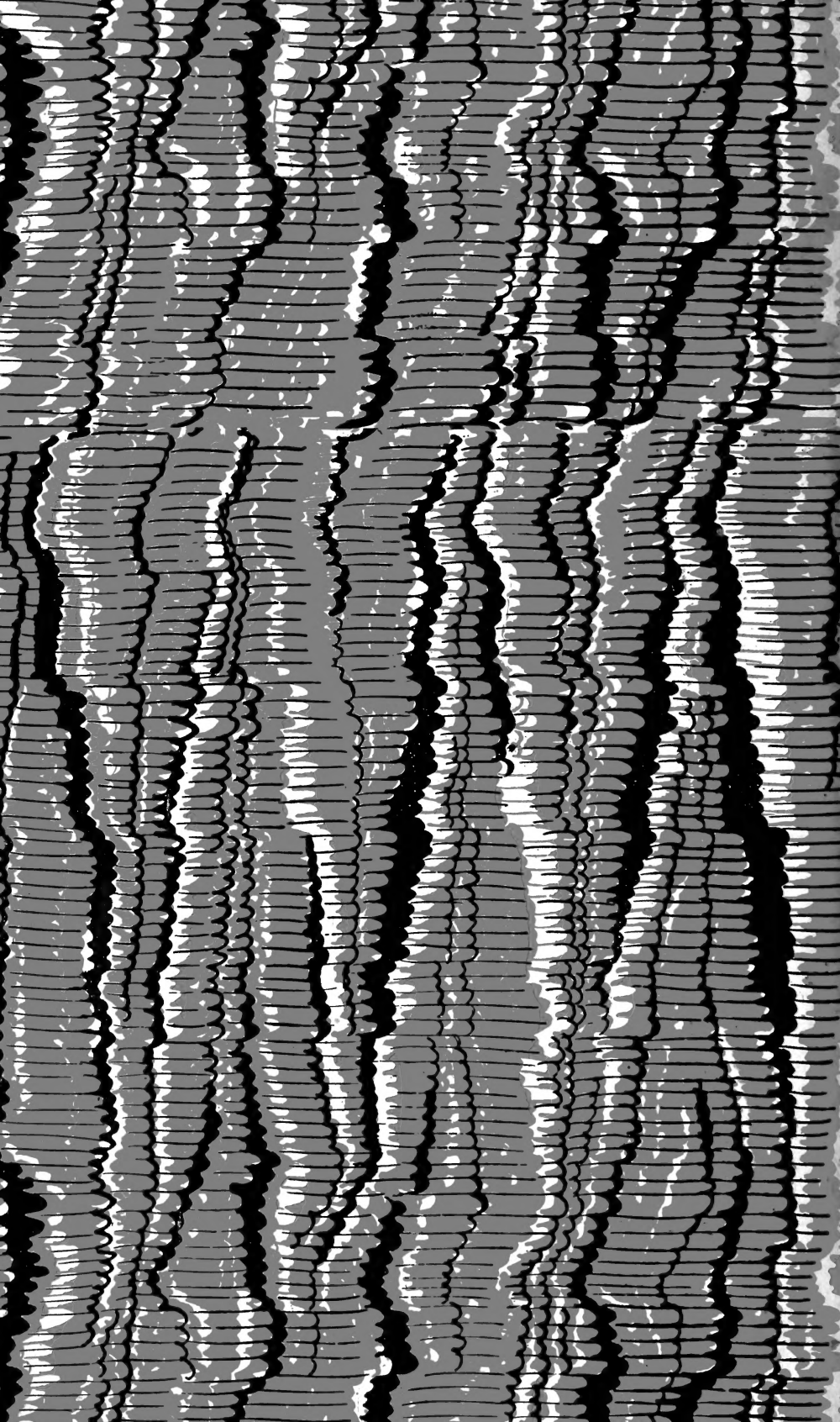
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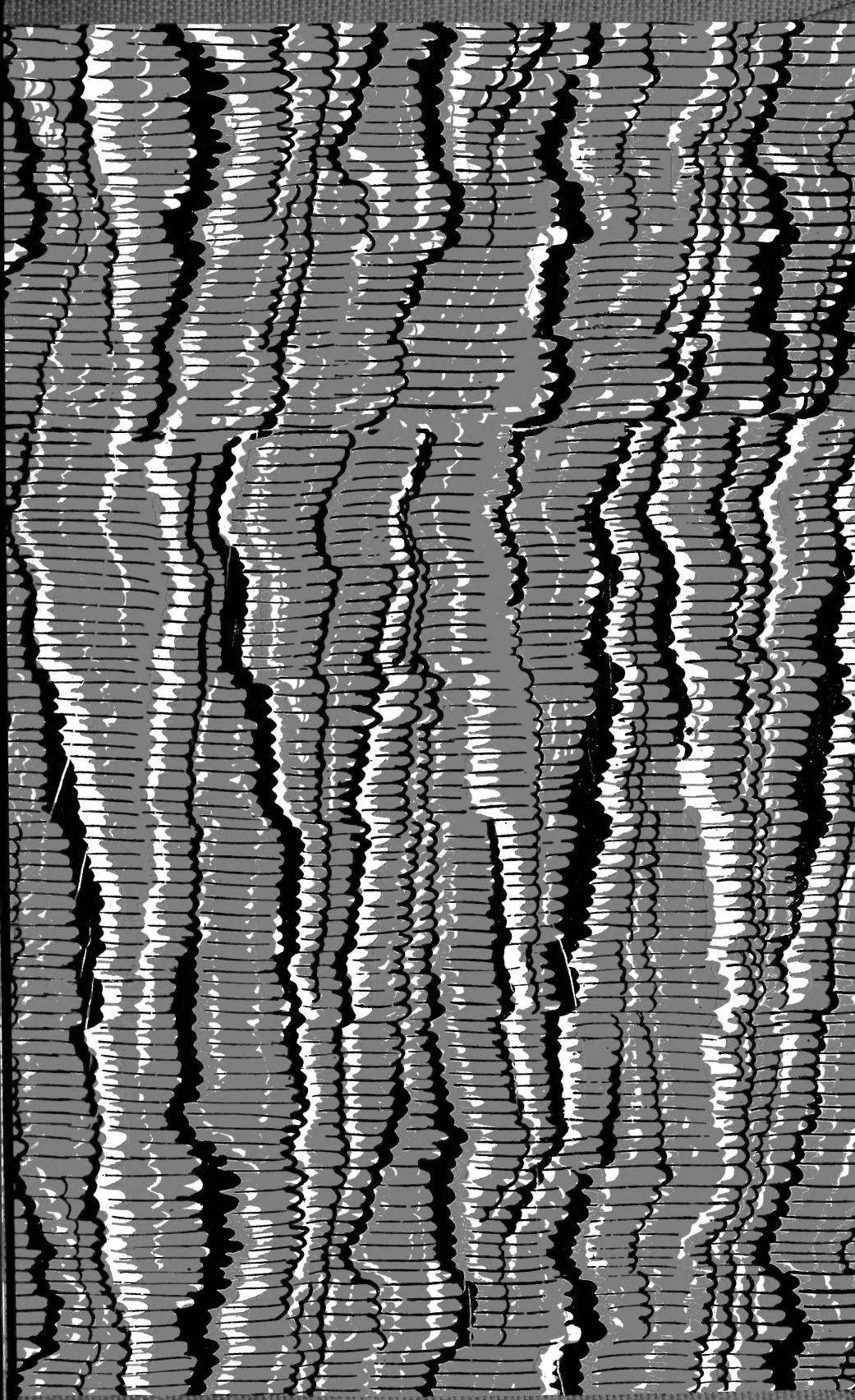












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